DR. WYNTER'S WORKS,

Three Volumes, complete, 18s.

Second Edition, Crown 8vo., price 6s.

Subtle Brains and Lissom Fingers;

Being some of the Chisel-marks of our Industrial and Scientific Progress, and other Papers.

By A. WYNTER, M.D., M.R.C.P., London.

Containing 39 Articles, amongst which will be found—

Fraudulent Trade Marks.
A Day with the Coroner.
Undersea Railroad.
Vivisection.
Restoration of our Soil.
Railways the Great Civilizers.
Physical Education.
Clerk of the Weather.
Village Hospitals.
Air Traction.
Illuminations.
Boat-Building by Machinery.
Doctors' Stuff.
Smallpox in London.
Excursion Trains.
Early Warnings, &c.

HRDLICKA COLLECTION

By the same Author, Seventh Edition, price 6s.

Our Social Bees;

Pictures of Town and Country Life, and other Papers, containing 45 articles, among which will be found—

London Smoke.
Mock Auctions.
The Suction Post.
Our Peck of Dirt.
The Artificial Man.
Britannia's Smelling Bottle.
Commercial Grief.
Aërated Bread.
Needlemaking.
Preserved Meats.
Wenham Lake Ice.
Turkish Baths.
Who is Mr. Reuter?
Candlemaking.
London Stout.
Sewing Machines.
Physical Antipathies.
Ocean Horticulture.
Brain Difficulties.
Human Hair, &c.

Also Crown 8vo., Seventh Edition, price 6s.

Curiosities of Civilization;

Containing—

The London Commissariat.
Food and its Adulterations.
Advertisements.
The Zoological Gardens.
Rats.
Woolwich Arsenal.
Lodging, Food, and Dress of Soldiers.
Shipwrecks.
The Electric Telegraph.
Fires and Fire Insurance.
The Police and the Thieves.
Mortality in Trades and Professions.
Lunatic Asylums.

London: ROBERT HARDWICKE, 192, PICCADILLY.

At all the Libraries, 644 pp., price 10s. 6d.

The Stream of Life on our Globe:

An attempt to reproduce, in the plainest language, some of the newest and most interesting discoveries relating to the first Appearance of Man upon Earth, and the gradual Growth and Laws of Life.

By J. L. MILTON, M.R.C.S.

Contents.

1. Beginning of Life.
2. First Dwellers on Earth.
3. First Builders.
4. First Wanderers.
5. First Colonists of Sacred History.
6. First Language.
7. First Alphabet.
8. The Battle of Life.
9. The Laws of Life.
10. Life in the Blood.
11. Life in the Nerves.
12. Life of a Giant.
13. Life of Men of Genius.
14. Life in the Waters.
15. Life in the Stars.

Crown 8vo. cloth, price 6s.

Holiday Papers.

By HARRY JONES, M.A.,

Incumbent of St. Luke's, Berwick Street, Soho.

Containing 37 papers, amongst which are—

Holidays.
Work.
Looking Back.
Pond-Fishing.
Out of Town.
Garden Games.
Sight-seeing.
Dinner at Greenwich.
Waiters.
School Treats.
Short Cuts.
Mobs.
Sea-side Life.
Sea Bathing in France.
Bretons *v.* Britons.
Mont St. Michel.
Going Abroad.
Back Again.

---

350 pp., Crown 8vo. cloth, fully illustrated, price 3s.

Dr. Lankester on the Uses of Animals in Relation to the Industry of Man.

PART I., One Shilling, contains:
Silk.
Wool.
Leather.
Bone.
Soap.
Waste.

PART II., Eighteenpence, contains:
Sponges and Corals.
Shell-fish.
Insects.
Furs.
Feathers, Horns, and Hair.
Animal Perfumes.

---

400 pp., Crown 8vo. cloth, fully illustrated, price 3s.

Dr. Lankester on Food.

PART I., One Shilling, contains:
Water.
Salt.
Heat-Givers — Oil, Butter, Fat.
Flesh-formers—Animal Food.

PART II., Eighteenpence, contains:
Alcohol.
Wines, Spirits, and Beer.
Condiments and Spices.
Tea, Coffee, and Chocolate.
Tobacco and Opium.

"Full of sound science, curious anecdote, and quaint illustration. Dr. Lankester has a singular power of illustrative keenness; and in the discursive lessons which he delivers on so many subjects, there is an overflowing wealth of minute collateral information which is always brought to the level of the last achievements of science."
—*Lancet.*

DIVISION OF PHYSICAL ANTHROPOLOGY

U. S. NATIONAL MUSEUM

THE HRDLIČKA LIBRARY

Dr. Aleš Hrdlička was placed in charge of the Division of Physical Anthropology when it was first established in 1903. He retired in 1942. During this time he assembled one of the largest collections of human skeletons in existence and made outstanding contributions to his science. On his death, September 5, 1943, he bequeathed his library to the Division, with the provision that *"_____it be kept exclusively in the said Division, where it may be consulted but not loaned out_____"*

Ales Hrdlička

METAMORPHOSES

OF

MAN AND THE LOWER ANIMALS.

WORKS BY THE SAME AUTHOR.

Études sur les Maladies actuelles du Ver à soie. 1859. 1 vol. in-4. Planches coloriées.

Nouvelles Recherches sur les Maladies actuelles du Ver à soie. 1860. 1 vol. in-4.

Essai sur l'Histoire de la Sériciculture. Brochure in-18. 1860.

Recherches Anatomiques et Zoologiques faites pendant un Voyage en Sicile, par MM. Milne-Edwards, A. de Quatrefages et Émile Blanchard. 3 vol. grand in-4.

Les recherches de chacun des auteurs forment 1 volume séparé, accompagné de nombreuses planches coloriées.

Souvenirs d'un Naturaliste. 1854. 2 vol. in-18 jésus.

Unité de l'Espèce Humaine. Paris, 1861. In-18 jésus de 420 pages.

METAMORPHOSES OF MAN

QL
981
Q2
E1864
SOA

AND THE

LOWER ANIMALS.

BY

A. DE QUATREFAGES,

MEMBRE DE L'INSTITUT (ACADÉMIE DES SCIENCES), PROFESSEUR AU MUSÉUM D'HISTOIRE NATURELLE DE PARIS.

TRANSLATED BY

HENRY LAWSON, M.D.,

PROFESSOR OF PHYSIOLOGY IN QUEEN'S COLLEGE, BIRMINGHAM; ONE OF THE LECTURERS ON NATURAL SCIENCE IN THE SCIENCE AND ART DEPARTMENT OF THE COMMITTEE OF COUNCIL ON EDUCATION, ETC.

LONDON:
ROBERT HARDWICKE, 192, PICCADILLY.
1864.

LONDON:
COX AND WYMAN, PRINTERS, GREAT QUEEN STREET,
LINCOLN'S INN FIELDS.

TRANSLATOR'S PREFACE.

IT may be said that the aim of all science is the discovery of grand natural laws, which control everything that holds a place within the universe. This is its final object; but in order to attain it, three very distinct processes must be brought into operation. Firstly, it is necessary to observe closely the various phenomena which Nature presents in all her works: by this means facts are established. Secondly, the information thus obtained, and which is unavoidably of a very heterogeneous character, must be submitted to a mental examination; those portions which are alike being associated with each other, and with relation to the phenomena they refer to: in this way, kindred ideas become grouped together. Thirdly, the mind is required to investigate the relationship between the ideas thus called into existence and the things which may be said to have, indirectly, developed them; and the result of this comparison is the framing of certain generalizations, which are then

termed laws. By the operation of these, or some such processes, have men been enabled to form all those general conclusions, which constitute the foundation of each branch of the natural sciences. It is, however, unhappily the case, that biology stands, in this aspect, lowest in the scale; for not only has the difficulty in carrying out experimentation been an obstacle of a very formidable character, but it has been customary among its devotees to arrive at fixed conclusions from very uncertain premisses. Hence the laws which control life in its widest limits have ever been imperfectly defined; and although Nature's statute-book has a certain existence, those of its leaves which have fallen into human hands have been so fragmentary, that at present we may safely aver, in the language of a celebrated anatomist, that "the known is very small compared with the knowable."

Such being the state of things, our deepest gratitude is due to the man who, uniting the results of his own inquiries to those acquired by the investigations of others, and lending a clear mind to the analysis of the whole, sketches for us even the rude and imperfect outlines of that plan upon which force is permitted to labour in the production of living beings. Professor De Quatrefages is the person to whom we owe our thanks; for, in the present volume,

he has brought together all the facts bearing upon the subject of generation, and by a cautious and impartial comparison of them, has succeeded in detecting that hitherto, to us, obscure scheme which governs the production of animal forms.

The immortal Harvey gave rise to the aphorism that everything living proceeds from an ovum; but though in his time, as in the present day, his dictum could not be disproved, there was a period in the annals of natural science when it appeared to be little better than a pure assumption. The reader is doubtless aware that, among the higher animals, the formation of new individuals takes place invariably in one and the same manner;—by the contact of sperm and germ, an ovum is developed, which, in its turn, gives rise to a being similar to those from which it proceeded. The discoveries of naturalists, however, demonstrated apparently that the production of individuals does not depend upon this combination of two dissimilar factors. This circumstance inaugurated an entirely new era in the history of natural science. It was found that certain insects (*Aphides*), entirely devoid of both germ- and sperm-producing organs, possess the power of bringing into the world new beings like themselves; males and females being absent, and the animals which originate the offspring being essen-

tially neuter, there seemed to be no other explanation of the phenomenon, than that reproduction by ova was as much an accessory as a fundamental process. The beautiful researches of Küchenmeister and Van Beneden showed that the tapeworm which infests the human and other intestines, produces, as its immediate progeny, creatures exceedingly unlike itself, and destined to live within the body of an animal of a very different character from that inhabited by their parent. Chamisso proved that there are mollusks (*Salpœ*) which by ova produce others devoid of reproductive organs, but which, in the absence of these structures, give rise to the sexual individuals by a kind of gemmation. Saärs' observations led him to believe that the *Polyps* present similar phenomena. How, then, were all these exceptional facts to be explained? In what light was sexual generation to be regarded? Were animals to be considered as being produced indiscriminately by two distinct processes — gemmation and ova-development?

In the following pages the author has grouped all the phenomena, in accordance with their real affinities, and, as the result of this subjective mode of inquiry, he has reduced all the varieties of generation to one common law, which he has termed Genea-genesis.

The expression itself, simply meaning the development of generations, does not involve a theory, although it is associated with one. It simply implies a fact patent to all zoologists. The theory, which is actually the embodiment of the law sought for, expresses itself in the following words :—*The formation of new individuals may take place, in some instances, by gemmation from, or division of, the parent-being ; but this process is an exhaustive one, and cannot be carried on indefinitely ; when, therefore, it is necessary to insure the continuance of the species, the sexes must present themselves, and germ and sperm must be allowed to come in contact with each other.*

There is another philosophic generalization framed by the author, and which it appears to us should follow, rather than precede the first. It relates to the manner in which the animal proceeds from what it has been as an ovum, to what it is in its adult condition. If we watch the development of any mammal, we shall see that during its entire progress from simple to complex, from an embryonic to a mature state, it has been confined not only within the uterus of the mother, but also within those membranous folds which really constitute its egg-shell. But, on the other hand, if we turn our attention from the mammal to the insect, we shall find that the product

of the ovum is very differently circumstanced. In its case, the nutriment which is necessary to the construction of its organism, cannot be supplied either directly by the yolk or indirectly by a draught upon the mother's supplies; the egg is too small to admit of the former, and the possibility of the latter is equally precluded by the transient existence of the parent. The materials of growth must therefore be derived from external sources; the embryo cannot be passive in the undertaking; and hence it is thrown upon the world to provide for its own development. What the membranous uterus and appended blood-vessels supply to the mammal, surrounding objects and the active exercise of its faculties furnish to the insect larva. Every animal, in journeying through the successive phases of development, assumes an immense variety of forms, in fact undergoes *metamorphoses;* in Mammalia, these are concealed from the view of the ordinary observer; in Insecta they are present to the gaze of the entire world. It is true, then, that all animal forms undergo metamorphoses, and it only remains to be shown why in some these alterations take place in hidden depths, and in others are exposed to common observation. This brings us to the next great law, which we may thus lay down:—*Those creatures whose ova—owing to an*

insufficient supply of nutritious contents, and an incapacity on the part of the mother to provide for their complete development within her own substance—are rapidly hatched, give birth to imperfect offspring, which, in proceeding to their definitive characters, undergo several alterations in structure and form, known as metamorphoses.

The above are the most important results of the inductive reasoning which the author employs, and we have given an idea of their nature, because they are not only the most striking, but are also those upon which our opinions are in exact coincidence. When, however, Professor de Quatrefages intimately associates metamorphosis and geneagenesis, we cannot agree with his conclusions; and when he assumes that vital operations are not to be explained by a reference to the known laws of force as it exerts itself through matter, and are only explicable on the supposition of a "vital power," we must decidedly express our dissent. We merely mention these circumstances in order to guard the reader against the impression, that the translator of a treatise upon science implies, by his silence, an assent to the doctrines therein enunciated.

In introducing this volume to the English Natural History world, we believe that we are filling a gap

in the scientific literature of the country, and are removing a want which long existed. Who has not felt the desire to possess some essay upon general embryology? And who has not found considerable difficulty in embracing a knowledge of the various modes of development presented by the members of the animal world? It is a book addressed not only to the working naturalist, but the amateur also, and whilst it will be found to possess the most copious references to the works of scientific writers on the subject of embryo-life, it is written in a style so unmarked by technicality as to render the reading of it a matter of comparative ease. Whether we have succeeded in rendering it as intelligible in its Anglo-Saxon as in its Gallic garb, remains to be seen; but that our efforts have at all events received both the sanction and assistance of the distinguished author, the following letter will be adequate testimony :—

PARIS, 30 *Mai*, 1864.

MON CHER MONSIEUR,

Je viens de recevoir et de lire vos dernières épreuves. Mille remercîments pour la peine qu'a du vous donner cette traduction. Elle est aussi exacte que je pouvais le désirer, et en tant que ma connaissance, malheureusement imparfaite, de la langue

anglaise me permet d'en juger, elle est aussi élégante que fidèle. Il ne me reste plus qu'à faire des vœux pour que vos compatriotes jugent mon petit livre aussi favorablement que vous l'avez fait vous-même.

Recevez, cher Monsieur, avec mes remercîments réitérés, l'expression de mes sentiments les plus distingués.

A. DE QUATREFAGES.

Monsieur le Dr. H. LAWSON.

To say that the author possesses the highest qualifications for the task of interpreting developmental phenomena, would be to argue ignorance on the part of the reader and a want of modesty on our own side. We shall therefore leave him to discharge the duty he has taken upon himself.

We have said our say; but ere we conclude, we would express our sincere thanks to the Author, Professor Huxley, Dr. Divers, and Messrs. Henry J. Slack and J. Daly, for their kindness in assisting us to examine and correct the proofs, as the following pages travelled through the press.

H. L.

June 20th, 1864.

AUTHOR'S PREFACE.

FOR some time past I have had an idea of writing a treatise on *General Embryogeny;* and in 1855 and 1856 I published a series of articles on this subject in the "Revue des Deux Mondes," with the double object of determining the results of my own researches, and calling the attention of an intelligent but unscientific public to the wondrous phenomena accompanying the development of living beings.

These articles are here reprinted, together with an account of the progress made since their first appearance. The doctrines and plan remain the same; but, independently of several additions and modifications of detail, I have almost entirely rewritten the chapter on Infusoria, and have added that on Parthenogenesis, the study of which began just at the period of my first publication.

Its origin will explain the character of the book. In the original articles I avoided being very technical,

merely giving accurate views, supported by the most striking illustrations. In the present volume I am forced to preserve this feature, unless I were to produce a completely new work.

Such as it is, I trust that this treatise may be accessible to all who are accustomed to serious reading. At the same time, it will present to naturalists the principal facts with which they are acquainted, arranged in a manner peculiarly my own, and with references to several works scattered here and there. Perhaps in these different aspects it may prove of service. Such, at all events, is the object with which I publish it.

March 15*th*, 1862.

CONTENTS.

CHAPTER I.

The Vital Vortex ... ... *Page* 1

CHAPTER II.

Metamorphosis Generally—Definitions 6

CHAPTER III.

Transformations of the Egg 15

CHAPTER IV.

Transformations which the Mammal undergoes within the Egg—Cell Theory 26

CHAPTER V.

Transformations which Mammals undergo after they have left the Egg 42

CHAPTER VI. *Page*

General Processes of Transformation—Conclusion ... 46

CHAPTER VII.

Metamorphosis properly so called—Metamorphoses of Butterflies 52

CHAPTER VIII.

Metamorphoses of Insects generally 69

CHAPTER IX.

Metamorphoses of Batrachia and Lampreys 87

CHAPTER X.

Metamorphoses of Myriapods, Crustacea, and Annelids... 94

CHAPTER XI.

Metamorphoses of Gastropodous and Acephalous Mollusks 104

CHAPTER XII.

Nature, Causes, and Processes of Metamorphoses.—Conclusion 110

CHAPTER XIII. *Page*

Geneagenesis.—First Phenomena of Geneagenesis discovered in Animals.—Agamic Generation (Aphides).—Reproduction by Fissuration and by Gemmation (Polyps, Hydræ, Compound Ascidians) 124

CHAPTER XIV.

Discovery of Alternate Generation (Salpæ and Medusæ) 145

CHAPTER XV.

New Explanation of Facts long known 157

CHAPTER XVI.

Geneagenetic Phenomena in Annulosa and Mollusca ... 166

CHAPTER XVII.

Geneagenetic Phenomena of Radiata 172

CHAPTER XVIII.

Geneagenesis in the Helminthes or intestinal Worms.—Spontaneous Generation 201

CHAPTER XIX.

Theory of Geneagenesis 219

CHAPTER XX. *Page*

Parthenogenesis, or Virginal Reproduction—Fundamental Facts 243

CHAPTER XXI.

Theory of Parthenogenesis 249

CHAPTER XXII.

Geneagenesis in Plants—Relation of the Animal to the Vegetable Kingdom 261

CHAPTER XXIII.

General Considerations—Conclusion 276

METAMORPHOSES

OF

MAN AND THE LOWER ANIMALS.

CHAPTER I.

THE VITAL VORTEX.

Ovid said, *our bodies undergo transformations; we shall be to-morrow, neither what we are to-day, nor what we were yesterday.** The poet-author of "the Metamorphoses" proclaimed therein a far more important truth than doubtless he imagined; and modern science, after three centuries of experiment and observation, has fully confirmed the words of the Augustan bard.

Unlike inorganic bodies, which are continually in a state of absolute rest, living beings are during their existence the seat of constant changes. Place an animal or plant in the scale-pan of a balance and endeavour to ascertain its weight with the exactitude of our most perfect instruments; you will have much difficulty in establishing equilibrium, and as soon as it is produced it will be disturbed, almost as it were by some inherent influence. The pan containing the animal will invariably be elevated, and that in

* "Corpora vertuntur; nec quod fuimusve, sumusve,
Cras erimus. . . . ."

which the corresponding weights were placed will be depressed. From this result we are forced to conclude that, in every moment of their lives, plants, animals, and even man himself, lose a portion of their substance. In order to preserve life, these constant losses must be incessantly repaired; and hence it results that the beings included in the two kingdoms must be supplied with food. Animals and plants, then, borrow from the external world certain materials, which, when properly elaborated, fill up the gap that is being constantly made. During the early life of *all* organized beings, and during the entire life of a certain number of them, the quantity of matter fixed by the organism exceeds to some extent that which is rejected, and from this the growth of the individual results. In the adult these quantities are usually exactly equal: hence his stationary condition. In the aged, finally, the force of decomposition gains the upper hand. But whether the loss and gain balance each other, or whether the one or the other is in excess, the double movement of arrival and departure never ceases.

Here a very important problem presents itself, which it is difficult enough to solve. Does the *vital stream* (to employ the appropriate expression) hold the entire organism under its control, or are there certain portions beyond its sphere of government?

This latter hypothesis has been, and is still, perhaps that of some physiologists who have urged to its greatest lengths, the comparison between living bodies and the apparatus used in our laboratories, and for industrial purposes. According to them, even the human body is something like a locomotive. The solid parts

of our organs represent collectively the wheels, tubes, pistons, &c. The machine receives but the coal and the water; it carries its grate with it, and prepares, without the direct assistance of the artisan, the steam required to set the apparatus in motion; similarly, say the mechanical physiologists, our body receives every day its supply of solids and liquids; it burns a portion of these substances to maintain the animal heat, and with the rest it builds up the organs which require it, and supplies the liquids necessary to put the whole in working order. In us, moreover, as in the locomotive, the solid matter once fixed, undergoes no change, or at the most is eventually worn out. The materials expended, and which must be re-supplied —the coal and water, the food and drink—are converted in the machine into smoke and steam, in man into steam (vapour) also, and into various secretions.

This theory we see, leaps over the difficulties which are presented by the history of development; it is framed for an organism fully formed and performing all its functions. But then, does it stand the test of application, and does it account for the facts with which the maintenance and decay of organisms supply us? Certainly not, at least in the animal kingdom.

In the adult and in the aged, numerous normal and pathological phenomena demonstrate the constant change of the solid, as well as of the liquid constituents. The now antiquated experiments of Duhamel, so ingeniously begun and carried out by M. Flourens, and the works of M. Chossat, leave no room for doubt on this point. The latter, among others, fed poultry and pigeons upon food from which he had removed the calcareous salts only. Thus he supplied these

birds with the materials necessary for the nutrition of their tissues, minus the inorganic substances, which, arranged in a living woof, give solidity to the bones. At the end of a certain period, fowls and pigeons became languid and died. Then the skeleton was found altered, and the bones attenuated or even perforated. The rest of the organism had been nourished; the bony tissue alone had not repaired its losses, and these were betrayed by serious injuries.* Thus the bones themselves, organs perhaps the least vital of all, and which the physiologists whose opinions we oppose have almost compared with brute matter, are, like the most delicate structures in the body, although to a less extent, under the control of the vital vortex.†

* The development of the bones and the molecular movements which take place in them, have been the subject of several works and very animated discussions. In a treatise like the present, I can only refer to a small number of these essays. Those of M. Flourens were first published in the "Archives du Muséum" for 1842, afterwards with numerous additions, in his work called "Théorie expérimentale de la Formation des Os," Paris, 1847. The experiment of M. Chossat which I described, was communicated to the Academy from his great work "Recherches expérimentales sur l'Inanition," which obtained the physiological prize in 1841.

† The results arrived at by the physiologists just cited, compared with those made known by MM. Serres and Doyère, Brullé and Hugueny, and with those deducible from a very remarkable analytical memoir read before the Academy by M. Fremy, lead us to the conclusion already clearly expressed by M. Flourens, that in the bones the vital force is occasionally subject to an arrest which is sometimes very prolonged. It is probable that the other tissues exhibit more or less analogous phenomena. But as regards the fact of the renewal of matter, it is sufficient to remove all doubt on this point, to read a few lines devoted to this question by Müller in his "Manuel de Physiologie," translated by Jourdan, 2nd edition, Paris, 1851, vol. i. p. 325.

We see that in the most hidden depths of living beings two contrary currents flow; one, molecule by molecule, constantly removing something from the organism; the other as rapidly repairing the breaches which, too much widened, would bring on death. At the end of a given period the total, or almost total renewal of the substance of the body, must follow from this double action.

This is a fact of the greatest importance. In the presence of this instability of the organic components, the decided persistency of form and proportion among living beings can hardly be understood, and the mind is enabled without difficulty to admit the possibility of the most extensive alterations. Truly, we are ignorant of the cause which brings these changes about, determines the order of their succession and includes them within impassable limits; but at all events, we may glance at one of the chief processes which Nature sets at work to create, develop, maintain, and destroy, under the influence of life.

CHAPTER II.

METAMORPHOSIS GENERALLY—DEFINITIONS.

All vegetable and animal germs, seeds, buds, bulbs, and eggs, have their origin in a few granules, scarcely visible under the highest magnifying powers, or even in a single vesicle, smaller than the point of the finest needle. Thus commence alike the elephant and the oak, the moss and the earthworm; and such is really the first appearance of what at a later period will become a man. We may conceive of the intermediate stages which exist between these points of departure and arrival, and of the immense field which here presents itself to the observer. Apparently exactly similar at the outset, all kinds of animals and plants must become distinct, and assume their special characters. Each of them, then, will present peculiar facts for research.

It is to the conquest of this land of wonders that modern Science marched, at first a little hazardously, and as it were groping its way; then with a firmer and firmer step, till at last it has discovered the *general tendencies*, if not the *absolute laws* of development. To glance retrospectively at this series of facts and ideas, even limiting ourselves to Zoology, would be to step far beyond the bounds that we have fixed; but among the subjects which recent researches have elucidated, there is one—that of metamorphosis—

which is familiar, at least by name, to most cultivated minds. To tell the truth, it comprises most of the others. This is why I have attempted to treat of it in its entirety; hoping thus to afford to all serious readers a general notion of the wonderful phenomena presented by the development of living beings.

The word metamorphosis has been for a long while employed in a restrained and an inaccurate sense. By it have been designated the very important changes undergone by certain animals, insects in particular, after proceeding from the egg. There was thus made of these alterations a group of phenomena, quite separate and distinct from those presented in the formation of the embryos of ordinary ovipara. With far more reason, we should regard them as having at most a very remote analogy with those processes observed in the development of vivipara. The term metamorphosis has been almost exclusively applied to modifications either of external form or of some extensive apparatus influencing directly the mode of life of the animal.

These were serious errors. The nature of a phenomenon does not alter with the locality in which it takes place, nor with its greater or lesser extent. As regards the passage from an egg-shell, or from the uterus of the mother, as regards the modelling of a single organ, or the formation of an entire body, changes of form and function lose none of their essential qualities. All are primarily caused by the force which animates matter, which incessantly destroys and rebuilds, through the assistance of the vital power, those wonderful structures which we call living beings.

We have shown elsewhere, why we must translate the celebrated aphorism, "Omne vivum ex ovo," * —Every living being, [and consequently every animal,] starts from a *germ*. With the organization of this germ begins a series of transformations, general or partial, rapid or tedious, which only terminate with life itself. Thus Harvey's expression leads us, as a matter of course, to this one,—every living being undergoes metamorphoses. For the most part, these latter are due to the same cause working through the same processes. To regard these as distinct orders of facts, because they are not readily identified, would be neither scientific nor correct.

It is this opinion which modern naturalists, and especially Dugès, Isidore Geoffroy Saint-Hilaire, Carus, and Burdach, have formed and expressed more or less distinctly; but M. Duvernoy was the first who thoroughly appreciated the idea, and systematized it in his lectures and writings.† In 1841 this naturalist

* "Revue des deux Mondes," March 15, 1850, and "Souvenirs d'un Naturalist," 1854. [The latter work has been translated into English.—Ed.]

† M. Duvernoy, a fellow-countryman and colleague of Cuvier, had even while very young attached his name jointly with M. Duméril to one of the great scientific undertakings of the age,—"L'Anatomie comparée." He was then nominated professor in Sorbonne, but soon gave in his resignation. After a very long interruption, caused by family affairs, he re-entered the field of science and began teaching, as professor of zoology in the faculty of Strasburg. Afterwards called successively to the Collége de France and the Muséum, he filled the two principal chairs of his illustrious master. He maintained the position which he held most worthily. Few men have given such numerous proofs of a sincere and energetic devotion to science. One may say of M. Duvernoy that he died on the field of glory; for almost on the day of his death, and in spite of the advice of his physicians, he

selected the metamorphoses as the text of his discourse to the College of France. Dividing the entire life of every animal into five distinct periods, he examined the species themselves, and the groups containing them, in these five periods, under the triple point of view of external form, internal organization, and performance of function. Four years hardly sufficed to complete this huge scheme, doubtless the best one calculated to give a complete notion of the animal kingdom. It would certainly be required nowadays. Since that time Science has enrolled many new facts, and the doctrines of twenty years ago have been very much modified. But I desire to recall here the part taken in this scientific movement by him who was my first master in Zoology, and my constant friend.

The germs or first rudiments of organized beings may be referred to three principal and distinct types, which are found in both kingdoms.* Animals especially multiply by eggs, or by free or attached buds. Further on we shall see more of these two modes of reproduction. Let us state here, that the first form alone is fundamental, and that the distinction between oviparous and viviparous animals, although still allowed in scientific parlance, is in reality only an apparent one. Baër, in discovering the mammalian egg, and M. Coste in discovering that it possessed the same features as the egg of birds, have established this

revised the proofs of a most important work upon the group of man-like apes, and especially upon the Gorilla. M. Duvernoy died in 1855.

* I have discussed this question of germs at some length in the "Souvenirs d'un Naturaliste," in the chapter headed "Saint-Sebastian."

fact, which is placed beyond doubt by the further and more searching investigations of these two naturalists, and the splendid works of the English and German physiologists, Barry, Bernhardt, Bischoff, Wharton Jones, Valentin, Wagner, &c. &c. It is at present satisfactorily proved that mammals, and even man himself, as well as birds and reptiles, proceed from actual eggs.

From one end to the other of the animal kingdom, the structure of these latter is probably identical in every essential particular. In mammalia, as in the Radiata or the Worms; in man, as in Hermella or Synapta, three spheres lying one within the other, and inclosed by a transparent membrane, constitute the germ. To these three spheres may be added various envelopes and accessory layers for their protection, or to aid in supporting the new creature; but, within the vitelline membrane may invariably be found the *vitellus* or yolk, embracing the *germinal vesicle* of Purkinje, which itself incloses the *germinal spot* of Wagner.

The exact function performed by each of these spheres is far from being known; but it is certain that the vitellus consists of organizable and nutritious matter. In some ovipara, this supply of food is extensive; a small portion is sufficient for the construction of the new being, which is nourished and grows at the expense of the remainder. The fish, for example, springs from the egg completely formed. However, it still carries attached to its belly a large bag, containing the greater part of the yolk-substance; and this being slowly absorbed, provides it with nourishment for more than a month after it has been hatched.

In all vivipara, on the contrary, the vitellus is very small. It would not suffice for the nutrition of the embryo, which is obliged to draw from external sources the materials requisite for its further development.

On account of this difference alone, it follows that certain germs can separate themselves completely from the parent, and others are forced to remain for some time in the interior of the latter. The egg of ovipara with a large vitellus is laid, that is to say expelled from the body, and often abandoned to every external influence without any protection save a delicate membrane or a thin shell of a mineral character. The egg of vivipara, left in a condition of complete activity, engrafts itself upon the maternal womb like a parasitic plant, absorbs from it the nutritious juices which it gives to the embryo, and grows *pari passu* with the latter. The phenomena which it exhibits, called into action by the necessity which exists for the nutrition of the young animal, alter its nature in no way, and at the final moment its special features make their appearance. In coming into the world, the mammal and man burst through thin envelopes, just in the same manner as a bird breaks through its shell. Birth is actually a process of hatching.

Now, in certain species the embryo, once fully formed and arrived at the fœtal condition, resembles its parents. At the moment of emergence from the shell, it presents almost the general form that it will maintain during life. The mode of performance of the principal functions is definitively fixed, and though a few organs may still be imperfectly developed, yet all are present, and none disappear. The alterations which

occur in the creature after emergence from the egg are very trivial, and relate chiefly to a few variations as to size and proportion. Such is the state of things among all vivipara,* and among a considerable number of ovipara also. Nature seems in these to have pursued a straight course. Every change impressed upon the germ has brought the new being nearer its final plan.

On the contrary, in all other oviparous species, the creature which springs from the egg differs in nearly every respect from its parents. It has neither their form nor their mode of life. Frequently it inhabits a different medium. We find in it complete apparatus undiscoverable in its parents; on the other hand, these latter possess other organs which are absent in their offspring. In returning to the original type, the descendant must undergo important changes. Here Nature seems pleased to prolong the route, and to arrive at the end of her journey only after many turnings; but, at all events, this route is a definite one, clearly marked out, and without a single cross-way.

In the two preceding cases, each germ gave rise to but a single individual, thus preserving its unity whole from birth to death. The three lower sub-kingdoms —Annulosa, Mollusca, and Cœlenterata—supply us with far stranger facts, whose real meaning is one of the latest discoveries of science. In certain species, always oviparous, each egg produces a creature bear-

* The marsupials (Kangaroo, &c.) may be enumerated as exceptions; but these vivipara, although having a double gestation, being hatched in the uterus of the mother, and carried for a while in the marsupial pouch, present in the main the same phenomena as ordinary mammals.

ing no apparent resemblance to that from which it sprung. Then this animal begets, of itself alone, and from all parts, a great number of other creatures, which most frequently are unlike itself. Here several individuals and several generations start from one and the same germ. Moreover the differences are seen not only in a single specimen examined at various periods of its life, but among all the generations which succeed it; these invariably differing from one another up to the last, which alone reproduces the primary type. True to our metaphor, we may say that the course pursued by Nature is at first single, and almost direct, but that it soon divides and subdivides into more or less tortuous paths, which lead invariably to the same terminus.

Although these facts are referrible to the same cause, and to common fundamental principles; although they are in reality but a continuation of the embryogenical phenomena, they are sufficiently different to admit of our distinguishing them by appropriate expressions. We shall see, moreover, that the simpler forms are involved in the more complex ones; and unless we would add to the difficulties of the subject, we must designate them by special names.

Consequently I shall term *transformation*, the series of changes which every germ undergoes in reaching the embryonic condition; those which we observe in every creature still within the egg; those, finally, which the species born in an imperfectly developed state, present in the course of their external life.

I shall retain the term *metamorphosis* for the alterations undergone after exclusion from the egg, and

which alter extensively the general form and mode of life of the individual.

Finally, I shall designate by the term *geneagenesis* * the changes which relate to generations themselves. It is upon this latter order of phenomena that I shall dwell more especially, as being the least known.†

* From γενεὰ and γένεσις, literally the reproduction of generations. Other expressions have been coined to designate the phenomena referred to here. Further on we shall examine this question in detail and make the facts known.

† M. Ed. Claparide published ("Bibliothèque universelle de Genève," 1854) a work on one of the principal phenomena of geneagenesis ("La Métagenèse, ou Génération alternante"), but it is impossible to approach this subject without touching upon other modes of development; and, in consequence we have sometimes treated of the same questions. Now I have remarked that this naturalist admits also three modes of development among the lower animals; viz., "1st. Development by metamorphoses, of which we see examples in Batrachia, Insecta, Crustacea, Arachnida, Mollusca, and a portion of the Annelida. 2nd. Development by metagenesis, either alternate generation, or through two degrees; of which we find examples among the Aphides, the Salpæ, the Helminthes, the Medusæ, and the Infusoria properly so called. 3rd. Mixed development, in which metagenesis and metamorphosis coexist, one beside the other, or rather blended together. This is the case in the Echinoderms." This extract shows that there are certain harmonies and also great differences between our opinions.

CHAPTER III.

TRANSFORMATIONS OF THE EGG.

From the almost exact resemblance presented by all the ova which have been already examined, we may conclude that the earlier phenomena of transformation are the same. Such appears to me to be the general result of the already numerous researches of hosts of naturalists. It is true, that with regard to the higher animals the harmony is far from being complete; but in very many of the instances the differences may be explained on the supposition that each observer perceived only certain phases of a complex phenomenon, which he was ignorant of in its entirety. To understand this entirety, we must have recourse to the lower animals; and even here we must select special groups. An untransparent shell, the opacity of the yolk, the length of time required for the alterations of form and texture, are very frequently insurmountable difficulties. It is because I found among annelids and mollusks, animals having rapid transformations and transparent eggs, that I have been able to distinguish the phenomena resulting from the vitality of the germ itself from those induced by impregnation, to determine the entire period of incubation, and to prove the extraordinary fact of an egg-shell becoming the skin of the future animal. Perhaps some of my readers may recollect what takes place in Hermella

and Teredo.* Apart from an author's egotism, and because the earlier stages of their development are more familiar to me personally than to any one else, I have selected these two species for the purpose of illustration. In addition to what we shall learn from an examination of these, I shall describe the chief features of mammalian development, but I shall not allude to the ordinary ovipara, whose embryogeny, seen from our point of view, would be of little interest.

As soon as the egg of Hermella and Teredo is laid, whether it be impregnated or not, it becomes the seat of internal changes, which do not alter its general form, and which we notice, as affecting its transparency. A mysterious power operates upon the yolk, accumulating its particles, sometimes at one point, sometimes at another, affecting the outer surface, and exhibiting in the mass shadowy figures which alter in form every moment. If we assume that similar changes take place in the mammalian egg, we can then understand how Messrs. Barry and Bischoff,

* My researches on these two creatures, the first belonging to the Annulosa, the second to Mollusca, were published in the "Annales des Sciences naturelles" for the years 1848 and 1849. In the articles on embryogeny, I laid especial stress on the changes dependent on the vitality of the egg itself, and particularly upon the phenomenon of segmentation which takes place even in unimpregnated ova. In 1849 I observed the same thing in Unio—(Comptes rendus.) Among the naturalists who have made similar statements I may mention one, M. Vogt, whose authority in a matter of this sort is very great, and who has seen segmentation take place in the unfecundated eggs of Firola (referred to by Siebold in his work on true parthenogenesis).

[The latter work has been translated into English by Mr. W. S. Dallas.—Ed.]

notwithstanding all the knowledge and skill exhibited in their researches, have not always agreed; and how the latter has occasionally observed ova of an exceptional character. The slowness of the changes which the yolk undergoes, and the utter impossibility of continuous observation, account easily for these apparent contradictions. Most probably the phenomena are in reality identical.* In Hermella and Teredo, the structure of the egg, whether impregnated or not, is modified by this agitation of the yolk. The germinal vesicle and the germinal spot both disappear. Their contents become mingled or blended, as it were, with the substance of the yolk. Here the analogy we are demonstrating is complete. In Mammalia, as in Mollusca, and Worms, the distinction between the three vesicles is lost, whether impregnation has taken place or not. In the highest, as in the lowest member of the animal scale, the egg thus exhibits its peculiar activity.

If the egg of Hermella or Teredo has not been impregnated, the movements of the yolk-mass increase in rapidity, and become more and more irregular. The egg at first becomes discoloured, and eventually decomposes. In like manner, doubtless, the un-

* Some of Messrs. Barry's and Bischoff's drawings have forcibly reminded me of the transitional appearances which I observed in the eggs of Hermella. Thanks to the rapidity of the phenomena in the latter, I have been able to see these appearances obliterated and replaced by others.—(Annales des Sciences naturelles, 1848.) I did not then attach any importance to this general fact. Deprived of this advantage, my fellow-workers have been unable to examine the matter as I have done. Moreover, since the publication of my memoir on the development of Hermella, everything that I have stated on the subject has been confirmed.

fecundated eggs of mammalia also disappear. Not only in the highest, but in the lowest member of the animal series, the object of the male element is to bestow, or rather to reveal, a vitality which already exists within the egg, and which exhibits itself by appreciable phenomena. Its function is but to regulate the employment of this vital force, so as to ensure its duration. Let us bear this important fact in mind now, and hereafter we shall be able to form an estimate of its value.

After the changes of which we have spoken, and whether the egg be impregnated or not,* there is formed on the surface of the modified yolk, in Hermella and Teredo, a kind of papilla, from which, as though they had been forced from the interior, one or two transparent globules make their escape. What is the real office of these globules? We know not. Already they have been observed in the egg of the rabbit, by Barry, Bischoff, and Pouchet; in that of the bitch, by Bischoff; and in that of the triton, by Wharton Jones; and they will be found in all probability in the other Mammalia, Reptiles, and Fishes. Vertebrata, Annulosa, and Mollusca resemble each other in this particular also.†

When the egg has been impregnated, the ex-

* M. Lacaze du Thiers has observed the expulsion of the transparent globule from the unimpregnated egg of Acephala.—(Histoire du Dentale, Paris, 1858.) This fact is of importance, in the presence of theories deduced from the penetration of the spermatozoïds into the egg.

† According to the researches recently communicated to the Academy by M. Ch. Robin, the globules referred to, are absent in certain diptera, the earlier stages of whose development present many other phenomena equally exceptional and strange.

pulsion of the globules is followed in the mammal, as in Hermella and Teredo, by a short period of repose. The germ recovers its spherical form which had been momentarily lost, and exhibits an entirely homogeneous structure; then the motion of the granules recommences, this time affecting both the internal and external portions. A ring-like constriction takes place about the middle of the vital sphere and deepens rapidly.* A second constriction then crosses the first at right angles; and this is followed by several others. As the grooves increase in number, the entire mass appears composed of hundreds of adherent vesicles, which give it rather the aspect of a raspberry; but the progressive multiplication of these vesicles gradually renders the surface smooth, and brings it almost to the original condition. The germ becomes transparent, and its outer layers begin to present the features of young tissue. These strange phenomena are also common to all animals.† Discovered in the frog by Messrs. Prévost and Dumas, they were soon observed in a great number of invertebrata; then in fish, by Rusconi; in mammals, by Bischoff; and finally in birds and scaly reptiles, by M. Coste.‡ At

* According to M. Ch. Robin, the first groove makes its appearance at the point from which the transparent globule has escaped, and on this account he terms the latter the polar globule. But this generalization is, to say the least, premature.

† M. Ch. Robin states that the diptera of which we have spoken are an exception to this rule. M. Lacaze du Thiers has informed me of a similar state of things which he has seen in other groups, but he wishes to confirm his observations by further investigations before giving them publicity.

‡ M. Coste has shown that, in birds, scaly reptiles, and cartilaginous fishes, the segmentation in the neighbourhood of the little

this point some slight differences are occasionally exhibited. In certain eggs with a large vitellus, a portion of the yolk escapes segmentation; but in all animals the result of this change is the formation of a primitive organized layer which embraces the yolk, and has been termed the *blastoderm*.*

These first traces of organization have hardly appeared when all resemblance between the various germs ceases. The germ becomes an embryo, and at the very outset exhibits the fundamental characters of the group to which the new being will belong. Up to this period both Vertebrates and Invertebrates have travelled together along the developmental road; but now they part, never to meet again. Henceforth the two great divisions of the animal kingdom, the two sub-kingdoms will remain entirely separate.

In Vertebrata, the organic elements—cells and granules—accumulate and arrange themselves, at one point in the blastoderm in the form of a minute spot, which is circular at first. This spot is the *germinal*

scar is obscure. This cicatricule is according to him the real egg; the remainder, or yolk, being merely an accessory body which masks and obscures the phenomena of the earlier stages of existence.

* The phenomena observed by M. C. Siebold in the planaria (Manuel d'Anatomie comparée), and by Messrs. Koren and Danielsen in the pectinibranchiate mollusks, form two remarkable exceptions to the general rule (Ann. des Sciences naturelles, 1852). But Dr. Carpenter has already shown that in the case of Purpura lapillus, these naturalists have been in error. The peculiarity of development in these mollusks is, doubtless, still exceptional; but, as regards the general processes of segmentation, and the expulsion of the globules (directive vesicles, Carus and Carpenter), they come under the general law.—("On the Development of the Embryo of Purpura lapillus."—Transactions of the Microscopical Society of London.)

area. It is the place where the creative forces exert their greatest power, or rather it is the embryo itself. The *area* increases very rapidly, and becomes oval. A transparent line appears in the direction of its greater axis. This is the *primitive streak* which already indicates the position of the future brain and spinal cord—the two great nervous centres that control the entire organism. Next, a series of obscure points placed symmetrically along this line shows us that the vertebral column is being formed.

The sub-kingdom being thus fixed on, the class to which the animal will belong is afterwards determined.

In Mammalia, as in the others, the proper coat—vitelline membrane—undergoes change also. Although at first thick and uncovered, it is soon surrounded by a layer of albumen, which is blended and grows with it. The egg is still free and unattached; but it soon throws out a number of delicate folds, [the first rudiments of the series of rootlets which at a later period it will dip into the substance of the mother's womb,] for the purpose of absorbing the juices intended for the nutrition of both the embryo and itself.

In Hermella and Teredo, as soon as the blastoderm is formed, the vitelline membrane, hitherto inactive, commences its labours. Its irregular folds disappear, it increases in thickness, and, like a sort of flexible egg-shell, it is fitted exactly to the incomplete embryo, as though it were an actual epidermis or skin. A few cilia are seen on its surface. At first they are as motionless as crystal filaments, but afterwards they commence jerking violently. Their number rapidly

increases, and their quicker and more constant vibrations disturb the body which carries them. This little being, which is no longer an egg and is not yet an animal, seems almost to poise itself upon the plate of glass placed in the field of the microscope. At last it undergoes its transformation. Suddenly the young larva escapes, as if urged by some mechanical force, and swims round and round, in the liquid, looking just like a little hedgehog covered with sharp spines.

Hermella and Teredo are animals which undergo two metamorphoses. We shall leave for a while these eccentric larvæ, but to study them at a later period, and will return to the mammalian egg.

We have seen that within the already large vitelline membrane, the germ lay, surrounded by the blastoderm, and that the germinal area was formed upon a portion of this membrane. The germinal membrane almost in its earliest stages is composed of two layers, which may be exposed by a little delicate manipulation. Very soon a third one is developed between the other two, and grows with them. All the organs, and also the various membranes which constitute the envelopes of the germ, are developed from these three layers. A special stratum formed from the external layer becomes the *amnion*, which like a veil of gauze surrounds the embryo, and secretes a large quantity of liquid in which the young mammal is plunged up to the moment of its birth. Another detaching itself gradually from the same point, doubles within the vitelline membrane, and helps to form the *chorion*, which is a kind of egg-shell. From the two other aminæ there is formed, at the posterior end of the

embryo, a sort of pouch—the *allantoïs*—which grows rapidly, and elongating itself like a long-necked balloon, is applied against the inner surface of the chorion. This allantoïs carries with it veins and arteries communicating with those of the embryo. Moreover, at the point of contact the vital activity of the membrane is increased. The villi of the chorion grow rapidly and become more numerous. Finally, the egg grafts itself upon the uterus of the mother, being retained there till the time of its birth; and from this period it receives nutrition at the expense of the parent.

While the transformations that I have been alluding to are going on, the germ itself is not inactive.

We have seen, that at the period to which I have referred, this germ is composed of modified yolk embraced by the blastodermic membrane, upon a limited portion of whose surface the germinal area and rudiments of the embryo are borne. In proportion as the latter assumes its special characters, and as the walls of its great cavities close in, it gradually withdraws from the surface of the sphere which contains it, and remains attached only by a sort of canal. At the end of a certain period the embryo and blastodermic vesicle are only united by a kind of hollow cord and a few blood-vessels, somewhat (if I may be excused the comparison) like the bowl and handle of a cup and ball. From this time the blastodermic vesicle is styled the umbilical vesicle. The latter in some cases becomes atrophied, and disappears, as in man and the ruminants; in others, on the contrary, as in carnivora and rodentia, it increases

in size, and fills those portions of the chorion which are not occupied by the allantoïs.

Thus, in Hermella and Teredo, the entire egg, including the envelope, is converted directly into a real animal. In mammalia, on the other hand, an embryo, consisting of a few elements, whose final condition will alone reveal their real nature, shows itself upon an almost imperceptible portion of the germ, and becomes more and more isolated. The germ itself contributes *directly* to the development of the new being only in the earlier stages of its formation. After the egg becomes attached to the uterus, and possibly before that period, it draws all its nutritive supplies from external sources, and the envelopes are the parts which play this important function intermediate between the mother and her offspring.

Indeed, there are not always such very considerable differences between vertebrata and invertebrata. In frogs, for example, not only is the egg separated from the mother, and consequently charged with the nutrition of the embryo, but even the germ itself encroached on rapidly by the skin, organizes, so to speak, layer after layer, and at the moment of its final transformations seems as though it had been directly formed; so much so, that some naturalists appear to think that it really is thus formed. On the other hand, Weber and Grube, two German naturalists, have described, in the leech and clepsine, phenomena recalling in many ways those which take place in mammalia.

However, it does not appear that in Annulosa, Mollusca, or Cœlenterata, there is a true germinal

area, and in no case can anything resembling a primitive streak be observed. This first indication of a controlling apparatus—absent in all invertebrates,—is never perceived, even in a transitional form, in the course of their transformations.

CHAPTER IV.

TRANSFORMATIONS WHICH THE MAMMAL UNDERGOES WITHIN THE EGG—CELL THEORY.

Having seen what occurs to the mammalian egg and its coverings, we shall now return to the embryo, bearing in mind, that though the various organs of which the body is composed unite in discharging one grand function—life,—yet each individual apparatus has its own particular part to play also. One set of structures is connected with animal life, the other with that series of phenomena common to animals and plants, and hence termed vegetal; whilst both derive their support from a nutritious fluid—the blood—which is borne to every tissue in the body by special canals, termed arteries and veins. Here, then, we have three distinct systems and organs; what do they arise from? From the three folds or leaflets of the germinal area, which we have described elsewhere.

The external or upper leaflet develops the organs of thought, sensibility, and motion; or, in other words, the brain, spinal cord, nerves, bones, and muscles, whose operations are controlled by the will. The internal or lower fold produces those organs, such as the digestive canal and its appendages, whose functions, though of the greatest import, are performed without our being conscious of them. Finally, the heart, veins, and arteries, are developed from

the intermediate leaflet or lamella. These groups of organs do not commence their development at the same period, nor do they at first present their characteristic features. Before assuming the latter, all undergo transformations. Now, unless we were to begin a special treatise on embryogeny, it would be impossible to give more than a general and abridged account of these phenomena here; and, moreover, we must be cautious in selecting our examples. We shall, therefore, limit ourselves to such facts as will enable us to form a general conclusion applicable to the entire animal kingdom.

Those who have observed the successive appearance of the various organs during the development of the embryo, state that the first structures apparent in mammalia are those most characteristic not only of the animal kingdom generally, but of the sub-kingdom Vertebrata; viz., the vertebral column, cranium, and the great nervous masses which they contain. The question arises, are these the earliest structures in all animals? In answering this query, if we were to depend on the results of direct observation alone, we should at once reply in the negative. It is unquestionable that other portions of the animal apparatus, such as the skin and locomotive organs, are the first seen; but then the nervous system, which is usually considered to affect the vitality of the others, is only observed when in a very advanced condition. Possibly it is the first to be developed, but owing to its extreme transparency, we are unable to detect it with the aid of our present optical apparatus.

In mammalia, the heart accompanied by the blood-vessels makes its appearance at an early date, and

shortly after the nervous system. The digestive tube is seen at a later period.

This order of succession seems necessary, when we consider that the embryo receives its nutritive supply from external sources, through the intervention of the blood-vessels. When this necessity does not exist, the order of phenomena is in all probability altered; in fact, we see this alteration take place in most of the invertebrates whose development we are acquainted with. The digestive system is formed before the circulatory organs, and occasionally the latter are completely absent, even after the young animal has been hatched, and has begun life on its own account.

We should be almost inclined to associate this law with the imperfect development of the circulatory organs of certain adult invertebrates, were it not that the same thing has been shown to occur in animals whose circulation is complete and closed. If, then, we would understand why this system is so slowly developed, we must examine another phenomenon, which though confusing to some, will be easily appreciated by those who can form a proper estimate of the function of the general cavity of the body and the office of its contained liquid.* In those animals which have a free general cavity, the various organs of the body are

* Elsewhere I have described at some length, the function of this general cavity (Souvenirs d'un Naturaliste); my remarks may thus be briefly summed up :—"Invertebrates have as a general rule, neither lymphatic nor chyliferous vessels. Moreover, they have no connective tissue in the literal sense of the word. Consequently we find the various organs separated from each other by spaces or *lacunæ*, filled with a peculiar liquid which represents both lymph and chyle. Besides, when the circulation is incomplete, the blood is poured from the vessels into these lacunæ and

as it were plunged in a *nourishing bath*, and consequently a heart and blood-vessels; in fact, a system of irrigation, is not at all required. Their presence or absence is merely indicative of a higher or lower organization. Hence it follows that the young and adults of many species do not possess a vascular system.

All the systems of organs whose order of succession we have been considering are connected with the preservation of the *individual*. Those connected with procreation, and which ensure the perpetuation of the *species*, appear at a much later date than any of the others. We must bear this general law in mind, for not only is it applicable to all animals which undergo transformations, but in those subject to *metamorphoses* and *geneagenesis* it is even still more marked.

The various apparatus we have mentioned are all complex enough, being each composed of several organs, and these again being built up of different tissues. Hence we naturally inquire how three folds of such a simple character as those of the germinal area, have been able to give rise to such a complicated machinery, and under what form the material which the vital force has thus transformed, appears in the beginning. Before going further, then, we must consider a few fundamental laws, and analyze a theory whose name at least is familiar to all anatomists.

All naturalists who have investigated this subject agree in stating that every organ consists in its ear-

there mixing with the products of secretion and digestion, constitutes a fluid to which the term '*nourishing bath*,' employed in the text, seems hardly inappropriate."

liest stage of a mass of homogeneous, transparent, gelatinous matter, which has little or no distinct structure. M. Dujardin has judiciously named this elementary substance *sarcode,* a term which signifies, as it were, the road or highway upon which the tissues set out on their journey to their adult condition. From this mass of living matter all the anatomical elements are produced, and then, by the union of these latter, the various organs of the body are formed also. All physiologists who have devoted their attention to the development of mammalia, and of the lower invertebrata, agree upon this point; and even when they do not draw the conclusion in set terms, it follows from their researches.

But then, is the *sarcode* directly transformed into tissue, or is there a series of intermediate changes? In answering this question, we come to a doctrine which has been almost universally believed in, in Germany, for the last twenty years, and which many distinguished naturalists of other countries have put their trust in also. We allude to that hypothesis which Schwann, a pupil of the famous Müller, borrowed in part from botanical science, and applied to zoology, under the title of the *Cell theory.*

Botanists admit the existence in plants of a primary anatomical element, which may be converted by a series of modifications into the several vegetable tissues and organs. * This element they term a *cell;* it is a small vesicle formed of a single or double

* For some years the theory to which I allude was regarded as having no exceptions; but the progress of knowledge shows us that it only applies within certain limits even to the branch of natural science which at one time appeared to bear it out fully.

membrane, and containing in its interior a slightly viscid fluid, and an exceedingly minute corpuscle, called a *nucleus*, which again contains within itself another, which is called *nucleolus*. These cells—spherical when isolated, or polygonal because of the pressure, when packed closely together—constitute cellular tissue, of which we have familiar examples in the pith and cork of vegetables. When these are elongated in the form of spindles, and filled with ligneous matter, they constitute the fibres of bark and wood; and still more developed, excavated, and fused end to end, they form the vessels by which the circulating fluid is transmitted. Now as these three tissues—cellular, woody, and vascular—form by their union, the roots, stem, branches, leaves, and flowers,—in fact every organ of a plant, it follows as a natural consequence, that every vegetable commences its existence as a cell; moreover, this organogenical law is fully borne out by comparative anatomy, some of the lower forms of plants being entirely composed of a single cell.

The foregoing remarks show us why botanists deem it of importance to be acquainted with the phenomena of cell multiplication and development. But even upon this question there has not been much harmony among them. Schleiden, who is one of the most distinguished botanists in Germany, put forward a theory on the subject of cell-formation, which has been adopted by his fellow-countrymen, and has found many disciples among the botanists of other nations also. According to him, cellular tissue is at first quite liquid, and gradually assumes a jelly-like appearance, without, however, the faintest trace of

organization.* Next a number of little corpuscles or nucleoli make their appearance in the mass, and these becoming surrounded by the gelatinous material, constitute as many nuclei. From each of these a delicate membrane is produced, which after a while completely incloses the nucleus, and thus converts it into a perfect cell. Each cell, as soon as it is fully formed, is capable of developing others by a series of processes, admitted by botanists generally. These processes are three in number. 1st. By budding from its outer walls. 2nd. By division, which may take place either by constriction of the entire cell, or by the formation of partitions in its interior. 3rd. By the development of free cells within it, which are eventually set free by the bursting of the parent one.

Schwann sought for the same state of things in the animal as in the vegetable kingdom. He fancied that he had discovered the similarity, and endeavoured to apply botanical theories to the development of the animal. Closely following Schleiden's view, he gave to the primary material, which we have styled sarcode, the name of Cystoblastema.† According to him, this amorphous substance was transformed successively into the nucleolus, the nucleus, and finally the cell itself. From the latter sprung every tissue, and consequently every organ in the animal body. Even

* M. de Mirbel, our distinguished physiological botanist, describes a similar substance, which he calls *cambium;* but according to him, the corpuscles or nucleoli of which Schleiden speaks, are only minute cavities gradually enlarging and forcing back the surrounding matrix, which when more organized forms the cell-walls.

† Κύστις a vesicle, and βλάστημα, a bud, or, figuratively, production.

the egg itself was a cell in which the germinal spot was the nucleolus, the germinal vesicle the nucleus, and the vitelline membrane and yolk the cell-wall and its contents. Finally, according to the German anatomist, the segmentation of the yolk, the raspberry-like appearance which we mentioned in another chapter, was but the production of a new series of cells within what he would term, *par excellence*, the parent cell.

Schwann's work was very highly thought of, and was supported, almost on its publication, by several distinguished men of science. That this success was deserved will be apparent to those who, on looking back, can recollect the condition of histology twenty years ago.* This doctrine was a very beautiful and captivating one; it established a decided fundamental relationship between the two grand sections of the organic world; it showed that all forms of organized matter, whether plants or animals, started from the same developmental point; and it simplified several complex and laborious researches; finally, it was confirmed in numerous instances, by the results of actual observation, and though, at the outset, a few exceptional cases presented themselves, it was quite fair to imagine that, after a while, even these would be overcome, and the theory would become a certain law. Gradually, however, these exceptions became more numerous, and even his most ardent followers were obliged to reject some of the author's opinions. Nowadays the comparison between the ovum and a single cell would hardly receive much support. More-

* "Mikroscopische Untersuchungen über die Uebereinstimmung in der Structur und dem Wachsthum der Thiere und Pflanzen." Berlin, 1832.

over, the segmentation of the yolk, and formation of the raspberry mass, cannot be due to the development of a series of cells, as Schwann asserted; for we find that, among certain mollusks and worms, the most complete lobes of the vitelline structure occasionally coalesce; thus showing that they are not provided with any distinct covering.*

Many serious mistakes, arising from the study of the higher animals exclusively, have been corrected by an anatomical investigation of marine invertebrata, and we find that such an investigation is fatal to the cell theory. It is quite true that this theory and the facts to which it is applied, agree in many instances. The majority of the mollusks, the Nemertes, Planariæ, Synhydræ, and almost all the creatures which I have described elsewhere,† have skins of a more or less decidedly cellular character; and, moreover, all these external tissues are primarily formed from cells. We know this to be the case in membranes lining the inner and outer surfaces of the various organs, but we cannot say the same of the organs themselves. We have never seen either muscular or nervous fibre begin its development in the cellular condition, nor

* I saw this for the first time in the eggs of Hermella.—(Ann. des Sciences naturelles, 1848.) It has since been observed by others.

† See the "Souvenirs d'un Naturaliste," 1842. Some of my readers may think that I allude to this work oftener than is consistent with modesty, but I know of no other in which this subject is treated of in so popular a style. I cannot refer my present readers to the "Annales des Sciences naturelles," nor to the similar publications in England and Germany. . . . . I trust therefore that I may be pardoned for alluding to a work in which the general reader will find much matter for which there is no space in a volume like the present.

have we ever found the slightest trace of a cellular formation in either of these structures.*

There cannot be the slightest doubt in regard to the non-cellular character of the muscular tissue. We have seen entire apparatus, fully formed, and quite perceptible, yet composed of sarcode alone. In certain mollusks, the digestive tube may be detected soon after it has separated from the general blastema; in this case the stomach, gullet, and intestine, have assumed their proper form and position, but there is no distinct cavity, and consequently no adult mucous or muscular layers. Among Annelids the development of the feet demonstrates the same fact. Furthermore, we have observed decided contractions take place in exclusively sarcodic masses, in which no reagent could show the fibres, although these are present at a later period.

Thus, we see that in certain instances not only the external features, but the intrinsic properties, pre-exist in the tissues, and that the latter originate directly in the sarcode, either by a sort of progression, or by condensation, or by an aggregation of materials drawn from the general nutritive supply of the being.

There are already many facts in opposition to Schwann's doctrine, and it is most probable that, as the subject is more considered, they will increase

* I may state here, that, in a most interesting memoir on the anatomy of Medusidæ, M. Agassiz, a naturalist of great repute in Europe, but who nevertheless abandoned the Old World for the United States, describes one of these radiates, whose nervous and muscular systems are entirely cellular; but even this exception from its exaggerated character is quite beyond the range of Schwann's theory.

in number. Several works which have been since published, even in Germany, present a decided reaction. Possibly injustice may follow infatuation. For our part, we should regret it exceedingly. We could never see in this theory those characters of truth and universal application which Schwann and some of his followers attributed to it, but we have not, on that account, denied the great benefits which it has effected for science. Like all general speculations which embrace a large number of isolated facts, it has enlarged the field of science, given more scope for research, and elucidated much of what had been before obscure. More fortunate than many of its predecessors, it is still to some extent correct, and even at the present time we might almost give it our support.

We may say of Schwann's theory, that, with a few exceptions, and save some questionable points which we cannot treat of here, it applies fairly to all the more lowly organized tissues of the body, and also—where the strata are sufficiently distinct—to the membranes which invest the various organs. There is, so to speak, a sort of histological relationship between the two great kingdoms. On the other hand, the more highly organized tissues, those which especially characterize the animal, are formed in the midst or at the expense of the sarcode. Up to this we have been speaking of the higher animals only, for as we approach the inferior extremes of the three invertebrate sub-types, we observe animals whose tissues are very indistinct, and of a half-sarcode nature; and in these instances the cell theory would be more in error than ever.

All organs spring from a *blastema*, which is pri-

marily composed of sarcode, and gradually assume their special features afterwards; but when first perceived they differ only in size from the adult forms. The embryo, in point of fact, is a miniature of the perfect being. In the course of development every animal exhibits very strange phenomena, both as to its entire economy, and in regard to special organs; and this is particularly the case with reference to mammalia. Daily, ay, even hourly, the scene is changed, and this unsettled condition applies not only to essential, but also to merely accessory organs. One might fancy that Nature was feeling her way to a conclusion. Here may be seen cavities being gradually partitioned off, divided, as it were, into distinct chambers, or drawn out in the form of canals, which, in their turn, are often refilled with solid matter and converted into ligaments; in another locality we observe previously solid masses transformed into cavities, membranous folds being rolled out into tubes, isolated portions of tissue drawn together to form a continuous organ, or even a mass hitherto entire, being gradually cut up into several new structures. Not only the form and proportions, but the relations also of the various mechanisms are being momentarily altered. Parts which at first had been closely related separate from each other and become distinct, and organs which had heretofore been distant from each other, form ties of close alliance. Those apparatus whose office is a temporary one rapidly increase in size, acquire an enormous volume, and eventually disappear altogether. Others are arrested in their growth at a certain period, and though all the organs

in their neighbourhood continue their development, yet they remain in their primitive condition, and may be detected in the adult, where they testify to a former state of things very different from the existing one. Thus we perceive that the history of embryonic development may be summed up as consisting in incessant transformations and constant activity.*

This condition of change is nowhere so strongly marked as in the circulatory system. Having for its office to supply the organs of the body with nutritious materials, it shares all their alterations. The various branches and ramifications of the vessels increase with the organs they supply with blood, and when the latter disappear, the blood-vessels undergo a proportionate diminution. Besides, this apparatus has its own peculiar changes, which affect not only the central portions and ultimate branches, but even the heart itself. The latter makes its first appearance as a transparent, solid, straight or slightly curved cylinder, which is converted into a tube by resorption of the

* In treating of the embryogenical changes of mammals, it is impossible to rise above vague generalizations. I cannot even mention the names of the authors to whom we are indebted for many of these interesting facts. There are very many of them, and besides, the memoirs and general works on this subject are rapidly increasing in number. However, I may mention among others, those of Messrs. Baër, Barry, Bischoff, Burdach, Coste, Dumas, Duvernoy, Flourens, Hausmann, Henle, Huschke, Kölliker, Lebert, Martin Saint-Ange, Meckel, Müller, Oken, Owen, Purkinge, Rathke, Reichert, Remak, Schultze, Serres, Schwann, Thomson, Valentin, Wagner, Weber, &c. M. Bischoff published a most interesting and valuable work, combining his own researches and those of other embryologists, which has since been translated into French under the title of "Traité du Développement de l'Homme et des Mammifères." Paris, 1843.

central matter. Next, it becomes S-shaped, twists upon itself, is constricted at one point, and widened at another, acquires dense and muscular walls, and is eventually converted into the large apparatus with four separate chambers, which occupies nearly the entire central portion of the chest.

In the embryo as in the adult, the heart is placed between the organs for the purification of the blood on the one hand, and those to which the pure blood is supplied on the other. In the fully-formed mammal, which leads an independent existence and breathes the surrounding air, the purifying organs are the lungs; but in the embryo, plunged in liquid and dependent on the mother for its nutrition, the function of respiration, or rather its equivalent, is performed by the envelopes of the egg. It is on this account that the circulatory apparatus is so different in the two stages.

In the adult each half of the heart is composed of two separate chambers, and comes in contact with one kind of blood (venous or arterial) only. The *right auricle* receives the *venous blood* which has flowed from all parts of the body and requires purification, and forces it into the *right ventricle,* which then propels it through a large artery to the lungs. Having been purified in the latter, the blood (now arterial) flows into the left auricle, and then from this into the left ventricle, from which a large vessel called *aorta* arises, whose numerous ramifications convey the vital fluid to the several organs of the body.

In the embryo the lungs are inactive, and the blood-vessels which supply them are quite rudimentary. To compensate for this absence of true respiration, a

special set of vessels intervenes, between the young animal and the coverings of the egg. The blood highly charged with nutritious matter flows from these envelopes toward the right side of the heart. As soon as it arrives there, it is permitted to flow into the aorta without passing into the lungs, by the aid of two contrivances for the purpose—the *foramen ovale,* an aperture through which the blood can flow from one auricle into the other; and the *ductus arteriosus,* or artery of communication between the great pulmonary vessel and the aorta.*

These anatomical peculiarities being only required during the embryonic condition, are not found in the adult. When the young mammal has been discharged from the mother's uterus, the atmospheric air rushes into the chest, and, dilating the lungs, causes the blood to flow toward these organs. Then the partition between the two auricles is gradually completed, the foramen ovale is stopped up, and the *ductus arteriosus* is obliterated, and not unfrequently disappears altogether. From this time forward the blood, in passing from one side of the heart to the other, must flow through the lungs, whose vessels have been permanently enlarged. At the same period the blood-vessels, which, having played the part of rootlets, had provided for the early nutrition of the fœtus, having been torn during birth, become atrophied and are lost. The young animal begins to feed itself, and the alimentary materials are prepared and transmitted to the digestive organs, by a mechanism which till now had been inactive.

* For a detailed account of these special apparatus, the reader will do well to consult the supplement to Müller's "Elements of Physiology," translated by Baly.—Ed.

The branchial respiration and its consequent peculiar circulation are followed by pulmonary respiration, and the true and permanent circulation of the blood. Instead of living on the juices of the mother, the animal now digests its own food. Thus in a few days takes place the last important transformation which a mammal undergoes; and since this converts the being from a parasite into an independent animal, we may fairly term it a *metamorphosis*.

The phenomena we have been describing, no matter what be their complexities or rapidity, succeed each other in regular order in each species of mammal, when the development is systematic; but they are occasionally interrupted by various disturbing causes, some of which we suspect, others we are entirely unacquainted with. Organs may have their transformations interrupted without the vital force being arrested, or the growth of the new creature checked; but then these organs depart from the natural type or plan. It is thus that monstrosities are produced. We see, therefore, that these departures from the normal plan take place at a very remote period of embryonic life, and that, *cæteris paribus*, the earlier the date of the disturbing cause, the more extensive will these departures be. Hence M. I. Geoffroy had good reasons for asserting that all mammalian monstrosities are congenital, or, in other words, that they take place prior to the birth of the animal. We may say, then, that all monstrosities are produced by an accidental, but decidedly embryogenical phenomenon. Having stated this general law, whose importance will be explained by the study of animals which undergo metamorphoses, we shall return to mammalia.

CHAPTER V.

TRANSFORMATIONS WHICH MAMMALS UNDERGO AFTER THEY HAVE LEFT THE EGG.

The development of mammals is, as we have seen, exceedingly energetic in the commencement; then gradually the organs appear in their proper order, assume their distinctive forms and proportions, and take up their right positions. The embryo, in fact, has become a fœtus, and has now strength enough to make its own way in the world. Finally, it is born; its lungs perform their function, its digestive apparatus discharges its duties, and its circulation is complete. Does this last step leave the organism, which has already undergone so many changes, in a state of rest? We saw in the first chapter how the balance answered this question, and here again we must employ accurate instruments in extending our observations to the animal kingdom. Is the infant in the same condition as the youth, or the adult as the aged? Is it not probable that at every period of life the form and proportion of an animal undergo alterations? And, unless we admit that our organs are the seat of perpetual changes and modifications, how shall we explain these alterations?

Of all the periods mapped out by the successive external features of an animal, there are none which are more remarkable, viewed from our stand-point,

than that at which the capability of procreation exhibits itself. This period is indicated in most animals by well-marked phenomena. Mammals, Birds, Reptiles, and Fishes throw off, as it were, the garb of youth, and assume the costume of adult age. Not only are superficial characters affected, and a few special organs completed, but new functions present themselves, and control all those which heretofore held the entire organism beneath their sway. In fact, the whole animal is altered in regard to those functions which most directly affect its general life. Here, again, man affords us a striking illustration.

Respiration is, as we know, a sort of combustion, and at every expiration we give off a certain quantity of carbonic acid. We can estimate the activity of this function by knowing the quantity of the latter gas formed by the combination of the oxygen of the air with the carbon derived from the decay of the tissues. Now, the researches of Messrs. Andral and Gavarret prove that respiration is a little more energetic in youth of both sexes than in adults.* Girls and boys of eight years old consume from five to six grammes of carbon per hour. This amount increases slowly, in proportion to each, up to the period of puberty. Till this period they are neither males nor females, but *neuters*. But as soon as the sexes are marked, respiration becomes twice as energetic in the man, although it remains the same as before in the woman. At about the age of thirty the former consumes from eleven to twelve grammes of carbon per hour, whilst the female

* "Recherches sur la quantité d'acide carbonique exhalé par le poumon dans l'espèce humaine."—Annales des Sciences naturelles, 1843.

consumes during the same period not more than six or seven.* Then as old age and the changes which accompany it efface the more marked distinctions between the sexes, the respiration of the female becomes more active, and although it never reaches the height of man's, it makes some approach to it. These strange results afford an argument to those uncourteous physiologists who see in woman but a man whose development has been arrested, and who, consequently, place her a degree lower in the animal scale.

We are far from supposing that the above opinion is correct, but the facts from which it is formed are not the less remarkable on that account. Here we see that, even when the organism is most complete, an important function is partially arrested and becomes stationary. Therefore this onward movement is not invariably a progressive one. This conclusion is fully borne out by an investigation of Mammalia generally, and of their mental faculties especially. Almost any wild animal may be tamed whilst young; for memory and intelligence are still present, and admit of its being educated to a certain extent. But when fully formed, instinct has the superiority, and the quasi-domesticated animal becomes a savage beast.† Very frequently

* The above apparent anomaly disappears when we recollect that at this period a new function is established in the female, which in all probability compensates for the deficient respiratory activity. This view is further borne out by the author's statement that the respiratory energy is increased in after-life. Why? Because then this peculiar function is not discharged.—Ed.

† Thanks to the researches of Frederic Cuvier, we know now that almost every animal possesses both instinct and intelligence; that is to say, its actions are partly the result of reason and partly

this change of character is exhibited in the external features of the being. The head of the young orang-outang, on the whole, resembles that of man; the skull is smooth and round, the forehead high, and the face hardly more projecting than that of certain human races. In the adult one, on the contrary, the cranium is covered with bony processes, the brow depressed, the face is prolonged in the form of a snout, and altogether the creature bears, in the highest degree, the stamp of everything that is purely animal. What we have said of the orang is equally true of all those apes which, from their resemblance to the human species, have been termed anthropomorphic or man-like.* The transformation which they undergo after a certain date, instead of elevating them, places them a grade lower in the scale, and therefore we may regard them as instances of that mode of evolution which M. Edwards has very appropriately styled *recurrent development*.

due to a blind instinct. Most of the writings on this subject are contained in an abridged form in M. Flourens' work, "De l'Instinct et de l'Intelligence des Animaux." See also M. Fée's work, "Etudes philosophiques sur l'Instinct et l'Intelligence des Animaux."

* On this point the reader should consult Professor Huxley's valuable work "Man's Place in Nature."—Ed.

CHAPTER VI.

GENERAL PROCESSES OF TRANSFORMATION—CONCLUSION.

Having sketched the more comprehensive features of embryonic development in general, and of that of mammals in particular, we shall now examine the various methods by which these phenomena are brought about. We saw, at the outset, that Nature does her work in a far more complete manner than some philosophers imagine, and that she accomplishes her purpose by a series of different processes, rather than by a single one.

Of these processes we may mention two by name—*Epigenesis* and *Evolution*; terms which have been for ages the standards of rival schools, and the subjects of many a noisy controversy.

According to the doctrine of Epigenesis, neither tissues nor organs exist in the embryo prior to their appearance; they are all formed upon the spot, successively, and, as it were, spontaneously also. The innate nature of each animal determines their form and structure. The Evolution theory, on the other hand, asserts that all the organs of the future being exist in the germ; that the latter has the power of growth alone, and is unable to give the being a hair, a feather, or a scale, in addition to what it already possesses, if it be an animal; or a leaflet, if it be a plant.

Epigenesis is really the starting-point of every organ in the body. We have shown this elsewhere,* and the details we have already given prove it to be unquestionable. Science armed with the optical instruments of the present day, asserts most positively that the blastoderm does not exist until formed from the elements of the germ. Thus, we see that even the first trace of the future being is a purely epigenetic formation, and we can say the same of all the organs in the body. All multiplication, according to Schwann's doctrine, is nothing but epigenesis; and this mode of formation is still more evident in those cases for which the cell theory makes no provision. An organ first appears in the blastema, and is developed at the expense of the latter, just as the primary membrane itself is organized at the expense of the altered yolk.

The germinal area is the first seat of these epigenetic formations, as each of its leaflets gives rise to a special series of apparatus, which are at first very simple, and made up of elementary materials. These, however, are afterwards completed, and develop adjacent and accessory organs. The alimentary canal, for example, has, when first formed, none of the glands attached to it, whose juices will afterwards be required in digestion. Soon, however, a little cul-de-sac, developing a blastema, makes its appearance at a certain point, and quickly exhibits a cavity with indistinct walls, which, though simple at first, gradually divide into branches. We perceive

* The general questions relative to the doctrines of Evolution, Epigenesis, and Accolement, are discussed at length in the "Souvenirs d'un Naturaliste."

here an excreting canal, and the earliest traces of a secreting organ or gland. These primitive lobules increase in number, and divide and subdivide, until at last that huge bile-secreting organ, the liver, is completely formed. All the other glands, the lungs, &c., are formed in an exactly similar manner. Hence it is very clear that none of these organs exist prior to their appearance.

Thus we see the developmental force first exhibiting itself within a special centre,—the germinal area; then in three secondary centres,—the three layers; and finally, in several different centres, as it helps to complete the various structures which at first were of a simple character. But epigenesis exhibits itself especially in laying the foundation of the embryo itself and of all its structures.

Each organ being at first roughly formed as it were, and exceedingly small, must eventually increase in size. Then, the purely epigenetic phenomena are followed by those of evolution, which present themselves under two principal forms.

An organ may grow without having its form or structure changed in any particular. The envelopes of the egg, the amnion of the embryo, and almost all the apparatus of the child, afford us numerous proofs of this. But in some cases organs must change their form, proportions, and size, ere they undergo this the most simple process of evolution. Now, in order to concentrate our attention, we shall here confine ourselves to two facts borrowed from human embryogeny. In man, the arms, when they first appear, are like a pair of little rounded paddles placed near the centre of the body, and the tail, which is now quite as long as in other

mammals, extends beyond the legs, which as yet are quite like the arms. At this period the human embryo is not by any means a bad representation of a certain species of seal. In order to be converted into the fœtal limbs and arms, these organs must undergo considerable modifications, and be increased in size.

In the construction of a new being there is something more than the creation and successive fashioning of organs which will eventually assume their adult characters. In the higher animals Nature always supplies those wants which the progress of development brings with it, and as these requirements are not unfrequently temporary, the organs which correspond to them are often transitional. Hence we often find her simultaneously building up one set of structures and destroying another.

A careful study of the circulatory apparatus would supply us with several curious examples, but we undoubtedly meet with the most remarkable instances in the organs of secretion. Among the manifold portions of the frame we find certain structures, which have been called after the great anatomist who first examined them carefully, the *Wolffian bodies*. These bodies remind us forcibly of the kidneys, at least as to structure, and appear to have a similar office to fulfil. They are seen at a very early period of embryonic life, and soon extend from one end of the body to the other, lying on either side of the intestinal canal. As soon as the true kidneys present themselves, these Wolffian organs disappear, so much so, that in a few adult mammals we can find but very questionable traces of them, and the detection even of these is a matter of some difficulty.

The organs whose functions are discharged during embryonic life do not all share the same fate. Some, as the *thymus*, which is situate in the chest, and the *supra-renal* capsules, are only arrested in their development, and are found in the adult, although seemingly without having any function to discharge: others are still employed and engaged in some new occupation. It is in this way that the vessels which are connected with the nutrition of the fœtal lungs are enlarged to such an extent after birth, that all the blood forced from the heart during a single contraction, can flow through them to the respiratory organ.

The important phenomena which are exhibited in the mammal from the first appearance of the germ, till death takes place, may be stated as follows: first, epigenesis; then evolution of the simple or complex type, formation, modification, progressive development, arrest of development, atrophy, and destruction, or appropriation of organs. All these phenomena, therefore, imply that, continual molecular currents are established in every portion of the frame.

If to this unavoidable conclusion we add the general law applicable to all vertebrates, that there exist in the embryo at the time of its most rapid growth, as well as in the adult, important organs which carry out of the body the worn-out materials, the term *vital current* will then appear in the sense we have employed it. It alone allows the performance of the various actions we have detailed already. Assuredly it is this which carries with it the materials of which the new being will be built, which lays

them down and distributes them, one moment accumulating them in one locality, anon drawing them away to another, and producing those manifold transformations which we have been endeavouring to describe.

CHAPTER VII.

METAMORPHOSIS PROPERLY SO CALLED—METAMORPHOSES OF BUTTERFLIES.

We have seen elsewhere that the germ of viviparous animals prior to rupturing its envelopes and leaving the mother's womb, is converted into an animal capable of leading an independent existence. All oviparous animals present, in the main, a similar state of things. The observations which have been published up to this, lead us to believe that a blastoderm, formed on the surface of the yolk, is the starting-point of the organism; and that the latter, assuming several transitory forms, and becoming more and more complex, undergoes, in the course of its egg-development, a series of successive alterations affecting the entire organism, as well as the structures which it comprises.

But, from the period of hatching, the newly-born animals constitute two distinct groups. The first have all the parental features; the second do not resemble their parents in any way. In producing the primary type, the first have only to increase in size, and undergo the modifications that we saw in the case of mammalia and man; the second, on the contrary, have to be completely altered. The latter, having undergone their *transformations* in the egg, must undergo their *metamorphoses* after they have left it.

For the sake of clearness, and for the purpose of

comparison, let us see in what this phenomenon consists, as we find it among insects where it has been longest known and most fully investigated. We shall select the Lepidoptera, commonly called butterflies, as an example, and study the life-history of one of the commonest species — the cabbage-butterfly (*Pieris Brassicæ*), which we can do almost with certainty by bringing together the facts observed by different naturalists.

All our readers must have seen these butterflies in their gardens, or in the country; they have black bodies, white ringed antennæ, and wings which are white on the upper side, but yellowish below, and covered with black spots, whose number and position mark the sexes. They are frequently seen in the months of August and September flying in pairs, sometimes in pursuit of each other, and occasionally rushing round and round, as though engaged in some severe contest. It seems as if a real struggle was going on. It is absolutely nothing of the sort; it is the prelude of sexual union, and has been investigated, described, and figured in all its stages by Réaumur, whose talent for observation seems almost to have amounted to genius.* The male urges his suit, and the female rejects it in true coquettish spirit. Finally, she settles down, but her wings are closely applied to each other, in this way covering the entire body. The male moves round and round her for a few moments, and then, as if he had taken his final departure, flies

* "Mémoires pour servir à l'Histoire des Insectes," tom. i. 1734. This work, in six large volumes 4to, is accompanied by a great number of plates, and even at the present day is unequalled of its kind.

almost out of sight; but this is evidently a ruse. As soon as the female unfolds her wings and exhibits her entire form, he returns quickly enough, but to no purpose; for she folds her wings together on his approach, and then the flirtations, pursuits, refusals, and pretended departures commence again.

These performances sometimes last for more than half an hour, no inconsiderable portion of a butterfly's lifetime. When they have ended, the female deposits its eggs, several hundred in number, upon some portion of a cabbage-leaf. The eggs are like little pyramids, three or four times as high as wide, and grooved by deep channels, which separate the rounded, undulating sides from each other. The Pieris arranges its eggs in a most artistic manner, side by side, and, having glued them firmly to the leaf, leaves them entirely to their fate. By far the greater number of them perish, but still some are hatched, and thus insure the perpetuation of the species.

Every one knows that there springs from each of these eggs a worm-like animal called a *caterpillar*, which must pass into the intermediate condition of *chrysalis* before it will become a perfect butterfly. We shall now pursue this series of modifications, beginning with the external ones.

The egg which our Pieris lays is much smaller than a millet-seed, and the caterpillar which emerges from it, is proportionally diminutive. When fully formed, however, it measures four centimetres in length, and about five millimetres in width, and four in depth. We see what a great difference there is in size between the animal when it emerges from the egg, and when it is fully formed, and how rapidly the increase

takes place. Moreover, this growth is not gradual, as in most other animals. We may describe it as occurring suddenly, and by a series of formative leaps taken at each of those periods ordinarily called *moultings*. In fact, as soon as it leaves the egg the young caterpillar eats with a voracity too familiar to our gardeners, but, nevertheless, does not increase in size.

After some days this enormous appetite is lost; the caterpillar becomes quite languid, and its skin loses its colour and appears to wither. It then crawls away to some sheltered locality. If we follow it to its retreat, we shall see it attach itself firmly to the ground, alternately contracting and inflating its body and twisting it about in every way; then resting for a while, as if completely exhausted, and finally commencing anew. Sometimes whole hours are spent before we can see the object of all these tiresome operations. Eventually the skin bursts at the third or fourth ring, and splits in a straight line from one end of the body to the other. The caterpillar now pushes out first its head and afterwards its entire body, and appears in a new skin as flexible and as brilliantly-coloured as ever. It has also increased in size, so that it would be quite impossible to inclose it in the case which before enveloped it. Its organs have increased in volume, but having been pent up and compressed by the old skin, when suddenly liberated they attained their proper size, as it were, through their natural elasticity.

There are several moultings gone through before the caterpillar arrives at its adult size and acquires its final characters. At this period we can distinguish but two anatomical regions in our insect—the head and

the trunk. The head is small, of a blue colour picked with black, covered with a hard skin, and provided with six simple eyes, which are quite separate from each other. The mouth, as in other caterpillars, is formed for dividing and chewing the tough leaves of cabbage and other cruciferous plants. It is provided laterally with a pair of solid horny mandibles, and a pair of less powerful jaws, which are partly concealed by an upper lip and a wide lower one. In the middle of the latter may be seen a small tubular elongated organ, pierced by a microscopic aperture; this is the spinning apparatus, by which is made the soft wool-like material which the animal will soon require.

The body of the caterpillar is of cylindrical form, and is composed of twelve almost similar rings. It is of a greenish or yellowish grey colour, marked by three yellow bands which pass from end to end, and is covered with black spots. These spots are little tubercles, each of which carries a white hair, easily seen with a pocket lens. There are eight pairs of feet for the purpose of locomotion, and, as in all caterpillars, these are of two kinds. The three first of each side are conical, jointed, and terminated by hooklets or little claws: these are the *horny* or *true feet*. The others are termed membranous or *false feet*. The latter are like large tubercles, whose ends are truncated and furnished with a circle of hooklets. The most remarkable feature in connection with these is, that the caterpillar can move them in every direction, can push them out, or draw them into the body so completely that there is hardly a trace left of the positions they occupied. To conclude this description of our caterpillar, we may mention that there is on each

side of its body and extending over ten segments, a series of little orifices, each of which is surrounded by a brown circle; these are the *stigmata*, or apertures through which the air is admitted to the respiratory organs, of which we shall say more further on.

The caterpillar of the cabbage butterfly completes its growth about the month of October or November. It now prepares for its first metamorphosis by ceasing to eat, and thus completely emptying its digestive tube; then it seeks the hollow of some tree, or hole in some neighbouring wall, and having found a suitable spot, it begins its preparations.

Unlike the silkworm, this caterpillar spins no cocoon for its concealment and protection, but undergoes its metamorphosis in the open air. It now commences covering the spot it has chosen with filaments which cross each other in every direction; and this silken couch, delicate in texture, but withal of considerable strength, serves as a solid and firm support for the hinder limbs. Then bending its trunk and head posteriorly almost to the middle of the back—like an acrobat who makes a hoop of his body—it fixes a thread first on one side and then upon the other, and continues the operation till it has formed a kind of girth, composed of about fifty filaments. This done, it straightens its body, and undergoes its last moulting; the animal however which emerges from the cast-off skin is no longer a caterpillar, but a chrysalis, which is sustained horizontally by the hooklets of its tail and the girth we have described, just like the reptiles and fishes which are too large for the cases in our natural history museums.

The Pieris in the new condition which it will maintain during the winter, bears hardly any resemblance to the caterpillar. The skin, which is dense and horny, is covered with a sort of varnish, thrown out at the moment of the metamorphosis, and rapidly dried. It has now assumed an ashy hue, picked out with black and yellow. The body has become thicker, but, as it were to compensate for this increase, has been shortened by about one-third. Instead of being made up of rings from end to end, it now exhibits two principal segments. The hinder one alone, which is short and conical, presents the annulose condition, although there is a keel-like elevation upon the dorsal portion of the anterior segment, and a kind of crest upon its under surface. The head and feet seem at first sight to have disappeared altogether. On closer examination, however, we can detect a series of rounded elevations and projections, arranged symmetrically. Knowing what this inert mass will eventually become, we can almost fancy that we see the various organs beneath the skin, or rather beneath the cement which invests it; the proboscis, antennæ, and wings being indicated in the same manner as the form and proportions of a mummy are rudely mapped out by the bandages which enshroud it. To all intents and purposes the chrysalis is a mummy.

About the middle of spring, or beginning of summer, the Pieris undergoes its second metamorphosis. Its envelope splits along the dorsal portion, and the organs which had been inclosed by the crests and elevations come out, as if from a case; then the entire animal disengages itself, and from the chrysalis coffin there emerges a perfect butterfly. At first its feet are

of too pliant a character to support the body; the wings are heavy, thrown into microscopic zigzag folds, and unfit for flight; and the proboscis, with its component halves often separate, is extended in a right line. But after a while the surrounding liquids are evaporated, the limbs are strengthened, the proboscis is adjusted and coiled up, the wings are unfolded, and the insect, which in its early days was "a creeping thing," and afterwards a motionless one, flies to the nearest flower and makes its first repast.

We shall now describe in a few words the being produced from the little worm which sprung from the Pieris' egg.

The body, which is entirely clothed with hairs perceptible to the naked eye, consists of three segments, which are separated from each other by well-marked constrictions; these three are: the head, the chest or *thoraæ*, and the belly or *abdomen*. The head is small, and has attached to it in front two long, horny, jointed, club-shaped feelers or *antennæ*, which had no existence in the caterpillar. The little *simple eyes* are still present; but in addition, a large round mass with a trellised surface may be seen on each side. These masses are the *compound eyes*, each facette of which is a true organ of vision; and since, according to the calculations of several naturalists, there are no less than thirty thousand of these facettes, it follows that the animal has this enormous number of distinct eyes. The mouth, which now, instead of being used for division and mastication, is only employed for suction, is admirably adapted to its new office. We can hardly find a trace of the upper and lower lips or of the man-

dibles. The jaws have been immensely elongated; their horny tissue has disappeared, and flexor and extensor muscles have been developed in its place. Each jaw is penetrated by nerves and tracheæ, and is grooved deeply on its inner surface. These organs, when placed side by side and soldered to each other, constitute a sort of tube twice as long as the whole body, and continuous with the mouth. From having been organs of mastication, they are now converted by this process of fusion into a proboscis, which the insect rolls or unrolls at will, and which can penetrate the deepest calyx and allow it to suck up the juices of the flower as perfectly as if a siphon had been employed.

The chest or thorax bears the legs and wings. The first correspond to the horny feet of the caterpillar, but are very unlike them in appearance. The limbs of the caterpillar were short and massive, those of the butterfly are long and slender. Besides, their structure is entirely different. In the butterfly's limb there are five distinct parts, and the last or *tarsus* is itself composed of five joints and a pair of hooklets. The four wings are attached in pairs to each side of the back. Each one is united to the solid structures through the intervention of a chain of horny pieces, connected together by strong ligaments and supplied with powerful muscles, and to these are due the suppleness and force which are exhibited in the movements of flight. From this basal portion spring four main nervures, which diverge from each other, and by their ramifications support the wing-membranes, which are thus stretched upon a horny frame. Notwithstanding their solid appearance, these nervures are really hollow in their interior, and are pierced by *tra-*

cheœ, or air-tubes, which extend almost to their extremities. Moreover they are covered by two exquisitely delicate transparent membranes, which, firmly united together, clothe the upper and under surfaces. It is to these that the little scales are attached which give the peculiar colours to this and other butterflies, being implanted in the membrane somewhat in the same manner as a bird's feathers are implanted in its skin. The caterpillar did not present the slightest trace of these wings or their appendages.

The abdomen, which corresponds to the hinder portion of the caterpillar's body, has lost all its *false* feet, but with that exception has undergone very little alteration. The general form has been slightly modified, the colour is no longer the same, but the abdomen is invariably divided into seven rather distinct rings.

Before proceeding any further, we must state, what it is of some importance to bear in mind: viz., that these moultings, metamorphoses, and alterations, although apparently occurring spasmodically, do not do so in reality. Beneath the veil of skin, which will be thrown off in course of time, even within those parts which will eventually disappear or be transformed into others, the new integument is being gradually formed; the general plan of the future animal is being drawn out, and the various organs which will afterwards be required are being organized. The old garment alone is cast off, both at the period of moulting and of metamorphosis. If we cautiously detach the old but still vital skin, a few days before the moulting takes place, we may see its successor lying beneath it. By doing the same with the caterpillar, a few

days before it passes into the chrysalis condition, we shall discover the rudimentary wings and antennæ. If at this period we cut off the little scaly feet, we shall find that when the butterfly emerges from the case, its legs will be imperfect.

Hereafter we shall recur to these facts: suffice it to say here, that the metamorphosis of the Pieris is gradual, not sudden; and that in this, as in every other instance, nature does nothing *per saltum*. We shall see presently that this conclusion, which is sufficiently demonstrated by an external examination, is further borne out by dissection.

Laying aside the internal changes which we have already alluded to, we shall consider neither the subcutaneous muscles nor those which are connected with the chewing apparatus, false feet, &c., and which disappear with them. We shall also avoid those associated with the existing limbs and the movement of the wings. We shall not refer to the hundreds of nervous trunks and filaments, to the numerous branches and ramifications of the tracheæ, which spring into existence and disappear with the organs they are distributed to. We shall confine ourselves to the study of Herold's beautiful researches on the metamorphoses of some of the large apparatus, and more especially of the digestive tube and nervous centres.*

The digestive apparatus which this caterpillar presents when it first springs from the egg, and even when it commences its transformation, is very simple in character.

* "Entwickelungsgeschichte der Schmetterlinge," 1815. In this splendid work, which even at the present day may be considered a model, the author takes the pieris we have been examining as an illustration.

The alimentary canal begins as a very short and wide *œsophagus*, and ends in an intestine, somewhat of the same kind, but which can hardly be said to consist of two regions. Between these organs we find a stomach disproportionately large, which fills almost the entire cavity of the body. In addition to these, two salivary glands, composed of long tortuous tubes, are attached to them in front, and six well-formed biliary canals, which represent the liver, are connected with them behind. Opening into the mouth and the spinning apparatus which we alluded to before, may be seen two peculiar organs, which extend in a tortuous manner along the entire length of the stomach, and whose office is the secretion of the fluid from which the silk is formed. Every portion of this digestive apparatus is calculated to extract the nutritious materials from the crude masses of unsubstantial food which has been imperfectly prepared by the action of the jaws.

Even on the second day after the caterpillar has been converted into the chrysalis, very considerable alterations may be observed. The œsophagus is narrowed and elongated; the intestine, similarly modified, is now divided into two well-marked regions; the stomach has been diminished by about one-half of its breadth and a quarter of its length; the salivary and biliary glands have been shortened, and the organs which secrete the silk have become smaller. On the eighth day, the entire digestive tube is exactly like a spindle one half of which is covered with thread, and which is loaded with lead in order to balance it. The œsophagus represents the upper portion of the spindle; the stomach corresponds to the middle, which is covered with thread; the small intestine to the thin

portion, and the large intestine to the loaded part. At the same period the salivary glands and biliary cœca are reduced by about two-thirds, and the silk-secreting organs appear as two very slender threads.

During the entire winter—that is to say, for five or six months of the year—these operations are suspended; but they are recommenced in fine weather, and continued till the insect is fully formed. In a short time the silk-forming canals have entirely disappeared; hardly a trace of the salivary glands is to be found; and the stomach, though preserving its former shape, has decreased in size; but to compensate for this, it has developed a new cavity called a *crop*, which is destined to assist in sucking up the juices of the flowers and retaining them till required by the insect. Moreover, the two intestinal regions have become more distinct, and the large intestine has developed an accessory pouch, not a trace of which existed hitherto.

We come now to the nervous system. In Annulosa generally, and hence in insects in every condition, this system is composed of two distinct portions. The *brain* is placed in the head just above the œsophagus. The other nervous masses, or *ganglia*, are situate below the digestive tube, where they constitute a ganglionic chain. The brain is united to the first ganglion, this to the second, and so on, by a series of nervous filaments, technically termed commissures. In each ring of the caterpillar's body there is a distinct ganglion; consequently there are in all twelve of these structures, equally distant from each other, with the exception of the two first, which are more closely approximated than the rest. The brain itself is very

small and is composed of two smooth lobes which are obliquely united, and give off a few slender nervous filaments.

Two days after the caterpillar has been converted into the chrysalis, the ganglionic chain has been shortened one-fourth, and various changes of alteration and concentration have begun. Some ganglia are approximated, others, on the contrary, are separated. At about the eighth day the chain has been shortened one-half. On the fourteenth the brain and first ganglion have come so close together that their commissures surround the œsophagus; the fourth and fifth ganglia have been fused together; and the sixth and seventh are hardly perceptible. Now there is a period of rest, brought about by the approach of winter. Then, after the latter season, the operations are recommenced, and when they are again arrested, after the last apparent transformation, there are only eight ganglia to be seen. The second, third, fourth, and fifth have given rise, by their fusion, to two large masses, which are placed in the chest quite close to each other; the sixth and seventh have completely disappeared, and their former position is alone marked by the origin of a few nervous filaments; the five posterior ones have undergone little or no change. Finally, the brain itself has become twice as large, its lobes have assumed a transverse position, and each of them gives origin to a large optic nerve which travels to one of the compound eyes.*

* This short sketch of the changes undergone by the nervous system has been taken in great part from the researches of Herold, because his investigations refer to the same insect (Pieris Brassicæ) which Réaumur studied. On which account we have been enabled

The changes which the organs of circulation and respiration undergo are not by any means as well known as those we have been describing, and this ignorance is due, most likely, to the great simplicity of the first, and the equally complex character of the second. In this caterpillar, as in every other one, the circulation is almost entirely lacunar. In it, as in the butterfly, there is a distinct heart, or rather its representation, in the form of a long many-chambered canal, stretching from end to end of the body. When the latter is shortened, this *dorsal vessel*, as it is called, is also diminished in length, and becomes more and more tortuous, in proportion as the regions of the body are mapped out and separated from each other.

This degradation of the circulatory organ is compensated for by the formation and distribution of a series of respiratory organs, or tracheæ. These open externally at the stigmata to which we have alluded already. They consist, in Pieris, as in all other cater-

to form a complete history of this butterfly. Those, however, who desire to pursue the study of the nervous system in insects, should consult the memoirs devoted to this subject by the English naturalist Newport, who was prematurely called from the field of science. His work upon the nervous system of the privet-moth (Sphinx Ligustri) is characterized throughout by clear powers of observation, accurate demonstration, and really scientific deductions. Daily, nay hourly, he followed the modifications which the nervous system undergoes, not only in the species on which his work is written, but also in the case of the nettle-butterfly. He proved that even in the course of a single hour the brain undergoes very appreciable changes in both its form and the disposition of its optic nerves.—("On the Nervous System of the Sphinx Ligustri," Philosophical Transactions, 1832.) The metamorphoses (general and special) of a butterfly are also described in the splendid work of M. Cornalia on the Silkworm, "Monografia del Bombice del Gelso."

pillars, of two great lateral trunks, reaching from end to end of the body, and giving off hundreds of branches and ramifications, which travel over the whole frame, penetrate the smallest cavities, and supply the most delicate organs. In all insects with the power of flight, and consequently in the Pieris, this apparatus develops a pair of pouches destined to contain air, and thus, of course, diminishes the specific gravity of the body. According to Newport,* it is only in the chrysalis that these organs are formed with rapidity. In Pieris, they first appear some time in autumn, and are half-formed before the winter; they remain at a standstill during this season, and assume their perfect form a short time after the last metamorphosis.

The function of all the organs we have already described is that of preserving or maintaining the life of the individual. They are all, moreover, in the full exercise of their duties from the moment that the creature emerges from the egg. Those organs connected with the perpetuation of the species are very differently situate. These are so slightly developed, and so imperceptible whilst the insect is in the caterpillar stage, that the penetrating researches of Herold could not demonstrate their existence. These organs are quite rudimentary, even at a period of five months after the conversion of the caterpillar into a chrysalis. It is only at the last moment, and just as the butterfly is about to make its escape, that they are to be seen in process of completion, whilst they undergo their entire development only in the perfect insect.

* "On the Respiration of Insects."—Philosophical Transactions, 1836.

Thus we see that this apparatus, though it marks out but an epoch in the lives of mammals and birds, is here characteristic of an entire change in the morphology of the animal. Its physiological signification is therefore, from this circumstance alone, of far greater value, and, as we shall see further on, this value is sometimes enhanced.

Here we must notice a very significant fact, and one which bears forcibly on the present subject. The female Pieris dies soon after depositing her eggs, and the male ceases to exist at a still earlier period. Matrimony is as fatal to them as it is to all insects, and their existence terminates when the preservation of the species has been insured. There is, however, an occasional circumstance which, by preventing the discharge of the functions essential to this final object, prolongs the usually short life of these insects to an extent beyond that which is intended. Some butterflies do not emerge from the chrysalis case till late in autumn, and then the cold temperature of the surrounding atmosphere retards their development, and winter comes on ere they have begun their amours.

In consequence of this, they retire to some sheltered spot, remain there during the whole season, and reappear in spring. Thanks to this condition of celibacy, the result rather of circumstances than of desire, their lives, instead of being limited to a few weeks, extend over several months.

CHAPTER VIII.

METAMORPHOSES OF INSECTS GENERALLY.

We have studied the complete life-history of an insect. By examining several species of each group from the same point of view, we are enabled to form a notion of the *ideal plan* upon which this class is constructed.

The typical insect would be an annulose animal, breathing by tracheæ, with a body composed of three distinct segments, of which the middle bears three pairs of legs and two pairs of wings, and which arrives at its perfect condition after undergoing two metamorphoses. Hence, independently of the time spent in the egg, its lifetime is divided into three separate periods, the first of which is characterized by both an external and internal activity, whose only object is the growth of the individual; the second by an internal activity alone, whose object is the modification of the individual; and the third by an internal and external activity, the sole object of which is the perpetuation of the species. Some insects are constructed *exactly* upon this ideal plan, and we need not go beyond the Lepidoptera to find an example. From the egg of the wood-eating cossus (Cossus ligniperda), a caterpillar is produced which spends two years or rather more in this stage, and then becomes converted into a chrysalis; the latter is transformed into a moth, which never eats anything, has no proboscis, and spends the few days of its

lifetime in the performance of those acts necessary to the production of offspring.

The greater number of insects differ more or less from this general type. Most of them, even on attaining their final condition, have still to maintain or complete their organization, and hence must provide for the nutrition of their bodies. Very many assume the perfect condition on leaving the egg, and, like mammalia, have only to increase in size. Others are entirely devoid of wings. These variations, however, are limited, and certain characters present themselves so constantly that there can be no question as to their being fundamental.

Every perfect insect is composed of a head, thorax, and abdomen; breathes by tracheæ, and has three pairs of legs. Looking at the insect class from our point of view, we can group together all these differences and affinities by regarding them as the results of a series of modifications of one and the same phenomenon. In common with all entomologists, we grant that metamorphoses may be either complete or incomplete.* The former term applies to those

* There may be also a sort of exaggerated metamorphosis, as M. Fabre has shown in his interesting researches upon the development of the meloës. The larva of this insect, before being converted into the chrysalis, passes through four distinct stages, which the author has termed *first or primitive larva, second larva, pseudo-chrysalis, and third larva.* But these changes, which are simply a series of moultings, are dependent upon the different conditions by which the animal is surrounded, on account of its frequent migrations, and have no reference to the internal organization of the creature. Hence they are included in the expression *complete* metamorphoses. This has been fully understood by the author of the remarkable papers upon "l'Hypermétamorphose et les Mœurs des Meloïdes," Annales des Sciences naturelles, 1857-58. Siebold, in his

insects in which there are three distinct stages of existence, corresponding to the *larva*, *nymph* or *pupa*, and perfect form or *imago*. But if we compare it with our ideal type, we shall see that an insect, although passing through these three stages, may yet want one of the essential characters already referred to. Thus, its last transformation may be as it were arrested at a certain point, and consequently the metamorphosis may be in reality incomplete. There is a sort of transition to those species whose changes are consecutive, slightly marked, or even absent.

With such exceptions we may look upon the following groups as insects which undergo *complete* metamorphoses—the Neuroptera (dragon-flies, day-flies, and white ants); the Hymenoptera (bees and wasps); the Coleoptera (beetles, lady-birds, &c.); and, finally, the Lepidoptera or butterflies. Having done with the latter, we shall now give a brief sketch of the other orders, and in doing so contrast the more remarkable points in their life-history with the facts already detailed.*

memoir on the metamorphoses of strepsiptera (Wiegmann's Archiv, 1843), and M. Joly, in his "Recherches zoologiques, anatomiques et physiologiques sur les Œstrides," 1846, have pointed out similar facts. The latter proved, moreover, that the anatomical changes and alterations of external form are simultaneous. He very correctly ascribes these phenomena to the conditions of life which the parasitic habits of the insect bring with them.—"Note sur l'Hypermétamorphose des Strepsiptères et des Œstrides," Comptes rendus, 1848.

* These metamorphoses do not always take place in the same manner in different orders. We may find a sub-order presenting peculiarities of its own, and even the individuals which it comprises may differ from each other as to the way in which these changes occur. Although limited as to the selection of species, I have chosen those which follow the general plan as closely

We shall now consider the Coleoptera, selecting the common cockchafer as an example. About the end of April, and some time after sunset, the female of this insect may be seen preparing for the hatching of her eggs. Having selected a light, well-cultivated, and manured soil, such as that of a kitchen garden, she digs a hole of about fifteen to eighteen centimètres deep, and deposits in it her eggs, which are thirty in number. This act accomplished, she ceases to exist. In a month after, a little whitish larva springs from each egg; it is half-twisted upon itself; its head is of a reddish hue and of a horny structure, and is provided with powerful chewing organs, and its body, which is soft, is composed of twelve rings, possessing six scaly feet and eighteen very well-marked stigmata.

The young larvæ lead a gregarious life at first. At this period the whole family is dependent for subsistence on the rootlets of the neighbouring plants, and the refuse vegetable matter scattered through the soil. Even on the approach of cold weather they still remain together; but they burrow deeper, and construct a large chamber completely removed from the influence of cold, where they pass the winter in common. When spring appears, these larvæ have become larger and more ravenous, and they can no longer enjoy each other's society, from the simple fact that no one locality could furnish them with enough of food; they now part company, each working its way up to the region of rootlets, through a little gallery or tunnel of its own. It is now that, under their

as possible, or which present facts whose application will be afterwards explained. The transformations about to be described are not quite typical.

too familiar name of *white worms*, they do so much mischief to our garden vegetables, nurseries, and natural and artificial plantations; sometimes destroying even huge trees by devouring their rootlets. On the approach of the cold season they again retire, only, however, to reappear in the following year. This subterranean life lasts for three years, or even more in occasional instances.

However, when fully grown, each larva makes a larger tunnel than ever, and constructs an ovoid chamber of a sort of mortar composed of clay and a gelatinous fluid which it secretes, and in this rough cocoon it is transformed into the *nymph* or *pupa*. In this condition it is very like a chrysalis; but the wings, legs, and antennæ, instead of being covered by the varnish before mentioned, are inclosed in special cases, and are applied to the surface of the body.

The cockchafer in its new condition remains torpid for five or six months. It wakes up toward the end of February and emerges from its case; but its body is still quite soft and uncoloured, and hence it is unfitted to brave the dangers of its future world. It remains in the ground, therefore, till its skin has become hard and strong, and finally leaves its subterranean abode about the end of April. It now flies to some adjacent tree, and though in its perfect insect condition, commences to devour the leaflets just as it destroyed the rootlets when it was in the white-worm stage.

In most classifications, the Neuroptera come after the Coleoptera; but in order to study, step by step, the phenomena we are now considering, we must invert the zoological order of succession, and pass on in the next place to the Hymenoptera.

To this group the Ichneumonidæ belong,—those insects which, by destroying other species in thousands, effect so much for our gardens, fields, and plantations,—benefits which we fancy very few are aware of. We shall study one of these insects, whose history can hardly be separated from that of the cabbage butterfly, and which has engaged the attention of Goëdaert, Swammerdam, Vallisnieri, and Réaumur. It is called the glomerate microgaster (*Microgaster glomeratus*).

This insect is like a small fly, and has four wings supported on nervures whose interspaces are large, a black body, yellow legs, and antennæ which are kept in constant motion. The female carries within the posterior portion of the abdomen, a lancet, or hollow sting (*ovipositor*), composed of three distinct pieces, whose function we shall now explain.

When she is about to deposit her eggs, she looks out for the caterpillar of the Pieris; as soon as she has found it, she settles down upon it, and grasping it tightly by the back, she pierces its skin with a single stab of this instrument, whose three component parts constitute a sort of hollow tube. She next drives it more deeply into the substance of the body, and at the same moment an egg escapes from the ovary, and, gliding down this canal, is deposited in the tissues of the caterpillar. The Microgaster then draws back its ovipositor, advances a little, and recommences this performance. In vain does the poor caterpillar writhe at every successive puncture; its enemy continues the operation in the calmest manner possible, and never gives over till it has effected its purpose, and deposited from forty to fifty eggs in places of safety. This

done, it flies away and speedily perishes. Once it has gone, the caterpillar no longer exhibits any symptom of suffering. Its wounds are healed, and it prepares to undergo its first metamorphosis, just as if nothing had occurred; but it undergoes no further development, and instead of a butterfly there spring from the chrysalis as many little maggots as there had been eggs.

In fact each of these eggs has produced a larva, with a smooth white body entirely devoid of limbs, and whose head, concealed in part by a sort of hood, is provided with a chewing apparatus well calculated to divide the caterpillar's tissues. These larvæ begin gnawing around them, at first carefully avoiding the more essential organs, and attacking only the fatty structures which surround and connect them. Afterwards having become more voracious, and just as their involuntary nurse has completed its growth and transformation, they devour everything remaining, and then piercing the skin which they have emptied of its contents, they come out and spin their pretty little yellow cocoons. In these they pass the winter without undergoing any alteration in form; but by the time spring arrives they have become *pupæ*, and a few days subsequently they appear as perfect winged insects.

Twenty or twenty-five—in other words about half of this brood—are perfect females, who very soon sacrifice as many caterpillars to the production of their offspring. We now see how the Pierides are destroyed by the Microgaster. Réaumur calculated that at least nine-tenths of all the ova are lost in this way, and of two hundred pupæ collected by M. Blanchard, only three gave rise to butterflies; the remaining

hundred and ninety-seven having been devoured by these ravenous ichneumons.* Assuredly the Paris gardeners ought to reverence this insect as highly as its mammalian namesake was respected by the Egyptians.

We shall now return to the Neuroptera and take for illustration a group, the short life of whose different species has received the attention of philosophers, naturalists, and even literary men, from the earliest ages.† Following the account given by Réaumur, we shall give a brief sketch of the life-history of the white-winged day-fly (*Ephemera albipennis*).

If, following the example of our distinguished guide, we were to take boat and sail up the Seine or the Marne, we should find that the banks below water-

* "Dictionnaire universel d'Histoire naturelle," article "Ichneumoniens."

† Aristotle was the first who treated of the ephemeridæ, in a passage where truth is curiously blended with the erroneous ideas of his age, and which may possibly interest the reader. "Near the river Hypanis, which flows into the Bosphorus," says the author of the treatise upon animals, "and about midsummer, may be seen several vesicles about the size of a grape-stone, which in bursting give rise to an animal with four legs and as many wings. These creatures live and fly about until evening; they become exhausted as the sun sinks in the west, and die when it sets: their life has lasted but a day; on which account they have been called ephemera (which means, lasting for a day)." Pliny and Ælian have but repeated Aristotle's statements. In the middle ages, Scaliger made known the fact that ephemeridæ were found in France on the banks of the Garonne, and that from their abundance at certain seasons they had been called *fishes' manna*. Clusius afterwards discovered them in Holland, and described their larvæ. At a later period, Swammerdam, Réaumur, &c., and in our time Kirby, Siebold, Léon Dufour, Burmeister, Pictet, &c., have studied them carefully; so that at the present day we may consider that the history of these insects is one of the best-known.

level were pierced by numerous little round holes from three to four millimètres wide, and usually grouped in pairs. These are the entrances of as many arciform galleries extending for about six to eight centimètres into the earth, and inhabited by ephemera larvæ. Each larva is about two centimètres long; its head bears two very large compound eyes, a pair of mandibles which are used in burrowing, and jaws adapted to grind the slimy mud upon which the creature seems to subsist. The thorax is quite distinct, and has six legs already attached to it; the abdomen ends in three long hairy filaments, and is covered with large fringed laminæ, which the creature moves with great rapidity. These laminæ are actual gills, that is to say, they are organs of aquatic respiration. Large tracheal trunks ramify through them, and extract from the surrounding water the air which is necessary to the preservation of life.

The ephemeron remains in this larval condition for about two years, gradually acquires its proper size, and then becomes a pupa. But this, quite the reverse of all the insects we have been describing, does not alter its larval mode of life. It lives in the same gallery, is just as active as before, and only differs in the possession of rudimentary wings attached to the upper part of the thorax. We see then, that this first metamorphosis is in certain particulars an incomplete one. It is not so with the second; this takes place every year at the same period, and occurs daily, nay hourly, without being influenced to any decided extent by variations of temperature. The nymphs or pupæ may be seen quitting the water for dry land, between eight and half-past eight every evening, from

the 8th to the 18th of August. The skin of the animal bursts very soon after, and the perfect insect throws off its envelope as easily as we would throw off a coat. It now flies away, leaving its gills, which have been replaced by stigmata, and its chewing apparatus, which it no longer requires, attached to the cast-off skin. Gradually the number of winged ephemera increases; about nine o'clock they fill the whole air; from this till about half-past nine they form perfect clouds, enshrouding the observer, and, falling upon him, and the ground, and water, like a heavy snow-shower, constitute heaps which are sometimes many inches thick. At ten o'clock there are only a few isolated specimens to be seen. In the space of a single hour these insects, which lived for two years under water, have been metamorphosed into air-breathing animals, with finely reticulated wings; have exercised their amatory passions in the atmosphere; have deposited masses of from seven to eight hundred eggs; and finally have ceased to exist,—deserving the epithet ephemeral in its modern sense, far more justly than their Hypanian brethren.

In the group we have just been examining, the metamorphoses are rather indistinctly marked. The organization of the ephemeron does not differ very widely from that of its larva. Moreover, the pupa is almost a fac-simile of the larva, leads quite as active a life, and, like the latter, inhabits the water also. The white ants and dragon-flies are pretty similar in these respects; in all, however, but especially among the ephemera, we find that the perfect insect corresponds to the ideal type. We shall see that this is sometimes unrepresented, and that in occasional instances the

characters of the insect at different periods resemble each other so strongly, that the transformations are almost undistinguishable. We come now to insects with *incomplete* metamorphoses.

The Diptera, or true flies, constitute a sort of connecting link between the above and the groups we have already considered. In these the three stages are very well marked, and certain metamorphoses are rendered more complex by the appearance of a new set of phenomena; but in the perfect insect we find that the posterior pair of wings is absent, being only represented by a couple of rudimentary organs called *balancers*, which regulate the flight of the insect. We see then that the Diptera are departures from our ideal plan.

Let us examine one of these flies,—the chameleon stratiomys (*Stratiomys chameleon*), which is common enough in the woods about Paris, and whose history has been clearly made out by Réaumur and Swammerdam. It is a large insect, a little longer and much wider than a bee. From its head spring two fusiform antennæ, its two compound eyes are separated by a hairy interval, and its large proboscis, which serves to abstract the saccharine juices from the nectaries of flowers, remains concealed, when at rest, within a special cavity. Its back, which is of a reddish hue, carries, independently of its pair of wings and balancers, two horny curved hooklets, which are directed backwards. Its belly is coloured brown, and is covered with white semilunar spots. Such is the perfect insect. Let us now see what the larva is like.

This is a sort of flat worm, inflated about the middle, terminating at both ends of its body in a snout-like point; it is about six or seven centimètres long, com-

posed of about twelve rings, is provided with a very imperfect buccal apparatus, is without a vestige of limbs, and its dense tuberculated body is like a piece of saturated parchment. It may be found in almost all our ponds, where it swims about somewhat in the manner of a leech. It can only breathe by air, and it does so in a very peculiar way. In the last segment of the body, which is much elongated, two very large tracheal canals, which pass from end to end of the larva, terminate in a single orifice; this orifice is surrounded by a bunch of branching filaments; and by the approximation of these latter it is kept constantly closed. As soon as the creature wants fresh air, it ascends to the surface, expands this filamentous organ, which thus constitutes a sort of float, and then, head downwards, it allows the atmospheric air to enter through the orifice, pass along the trachea, and so fill the entire body.

Réaumur has not told us how long the stratiomys lives in the larval condition. Invariably about the beginning of summer we find some of them twisted in a zigzag manner, and quite motionless and stiff; and if one of them be carefully opened, the fully-formed pupa may be seen in its interior. At the moment of its metamorphosis the stratiomys detaches itself as completely from the larval skin as occurs in the case of other insects; but instead of emerging from it and throwing it away, it still remains within it, thus saving itself the trouble of preparing a chamber in the earth or spinning a cocoon. In fact this skin forms a kind of house for the pupa, which in its present condition it is unable to fill completely. In assuming its nymph form, its body is so much con-

tracted that it hardly extends over five of the larval rings. But, as it were to compensate for this, the eyes, proboscis, antennæ, feet, and wings, have been added to the outer surface, and important anatomical changes have also taken place within. The larval skin, which thus forms a sort of shell for the pupa, being in great part empty, floats upon the surface of the water. After five or six days the nymph begins to move about in this case, which incloses it; and finally the latter bursts above, and the stratiomys, disengaging its limbs of their envelopes one by one, springs from its floating cradle. More fortunate than most aquatic species, it is incapable of being submerged, and consequently has little dread of shipwreck; and it is whilst treading as securely upon water as on land that it casts off the last garments in which it had been enswathed.

Leaving the Diptera, we find only insects which have incomplete metamorphoses, or none at all. It is usual to state this fact alone, but the generally accepted notion that we ourselves are developed in obedience to the same general principles as those which control the formation of insects, allows us to go a step further, and to regard all these modifications, and even the entire absence of the phenomenon, as the result of two immediately distinct causes, or at least as the products of two very different processes. The incompleteness of the metamorphoses may be due either to a premature development of the insect while within the egg, or to an arrest of development after it has been hatched. The entire absence of metamorphoses is owing to the influence of these two causes combined.

The Orthoptera, including the grasshoppers and crickets, and the Hemiptera, embracing the bugs,

cuckoo-spits, and lantern-flies, undergo very indistinct metamorphoses, for the simple reason that in springing from the egg, they possess almost all the characteristic features of the perfect insect. Hence, they do not exhibit those varied modes of life which we find among other species. The larva of the grasshopper, for example, leaps about, and browses upon the young herbs just as its parents did; the organs of locomotion and digestion having had their adult forms, and relations to each other, from the very commencement of its existence. It is true that its generative apparatus is still to some extent imperfect; but even at this period the future female carries at the end of her abdomen a sort of doubles word, which is nothing less than the *ovipositor* by which the eggs will eventually be placed in some sheltered portion of the soil. It wants but wings and an increase of size in order to be a perfect insect in outer appearance. It grows at each period of moulting, and the organs of flight soon appear in the form of stunted projections. At this period the nymph stage begins. Without changing its mode of life, it continues its development, and after the last moult, the wings acquire their full size; the grasshopper has arrived at the perfect condition, rather by a series of *transformations* than by *metamorphoses*.

Insects with incomplete metamorphoses due to premature development, usually resemble the ideal type when they reach their perfect condition; those, on the other hand, whose metamorphoses are incomplete, because of an arrest of development, are always more or less departures from the common plan. This brings us to the Flea tribe.

The eggs of the female flea are scarcely as large as

the head of the smallest pin, and the mother when laying them spreads over them little particles of dried-up blood. From each of these eggs springs a diminutive whitish larva, which soon assumes a brownish tint, and carries a small tuft of filamentous hairs upon each segment of its body. Although devoid both of legs and eyes, this larva is not the less active on that account, and is very well able to supply itself with nutritious food. In the course of twelve or fifteen days it has undergone its complete development. It then spins a cocoon, composed of threads of very fine silk closely interwoven, but which, being extremely transparent, allows us to watch the progress of the transformations which are going on within. As in the insects before mentioned, the nymph is perfectly motionless, and with the exception of the wings, exhibits all the structures of the perfect creature, folded up, and, as it were, shortened also. The adult flea can leap famously, but he cannot fly. In this instance the metamorphosis is incomplete, because of the non-development of the organs of flight.

Sometimes the arrest of development affects the internal organs alone, leaving the outer essential structures to be fully formed. In these cases, however, the metamorphosis is just as incomplete.

It is in this way that naturalists account for the peculiar characters of certain individuals which constitute by far the greater portion of every insect colony, and which, from the fact that they are neither males nor females, have been called *neuters*. The latter are really females, which have been modified by the combined influence of an innutritious diet and close confinement. As far as bees are concerned, this

fact has been incontestably proved by the observations of Réaumur, Schirach, and Huber. The cell which contains the larva of the *queen bee*, or, in other words, that of the egg-laying insect, is much larger and better constructed than any of the others. Moreover the future monarch is supplied with a peculiar form of food. When the bees wish to produce a queen, they break down several intercellular partitions, and enlarge and strengthen some of the cells; next, they supply the larvæ they contain with that peculiar food which is reserved for royal mouths alone; and under the stimulating influence of this new system of diet and hygiène, those larvæ which would, under other circumstances, have proved neuters, are converted into fertile females, capable of laying from thirty to forty thousand eggs. Furthermore, should any of this prolific *pâtée* fall into the neighbouring cells and be eaten by the larvæ which have been placed under ordinary conditions, even these are raised a degree in the animal scale, and become semi-fertile females.*

In bees, white ants, and emmets, in fact among all monarchical or republican insects which live in colonies, the neuters are abortive females. Being from this circumstance removed from the preoccupation and duties which require the whole life of the perfect insect, they strike out a new path for themselves. It is these alone which, under the name of *workers*, do all the labour, tunnel out the subterranean chambers, or erect the habitations, and nurse the eggs and young of the colony; it is these which, at the risk of their

* Hereafter we shall describe the reproduction of bees in detail. (See the chapters on Parthenogenesis.)

own lives, protect and defend those of the whole community. Looking at it from a mode-of-life point of view, we may say that *incomplete metamorphosis* produces a series of new beings.

Normal metamorphosis may be as it were diminished either by the premature acceleration of certain parts, or from an arrest in their development, or from their entire absence. Each of these causes acting separately alters the phenomenon differently; when united, they suppress it completely. An insect which undergoes no metamorphosis, departs so widely from the ideal type, that it may be considered as external to the class to which it belongs, if we view it in a physiological aspect; and its exceptional nature is represented by negative characters. It never possesses wings, and consequently is never, properly speaking, a complete insect; for organs of flight belong as exclusively to insects among invertebrata as they do to birds among vertebrata, and they are quite as characteristic of one group as of the other.

Besides, as we have already seen, the existence of wings and their *functional* development are closely associated with metamorphosis. They never exist in the larva, nor are they to be found even in the nymph; they only make their appearance at the very last stage of the animal's existence.

All insects of powerful flight, and which can remain on the wing for a considerable time, have to undergo metamorphoses; no insect whose metamorphoses are incomplete, not even excepting the celebrated voyager grasshopper,* is possessed of these advantages. On

* The voyager grasshopper (Acridium migratorium) is that species of the family Gryllidæ whose heavy columns often ravage entire

the contrary, there are many of them which never possess any organ of flight at all. Insects which undergo no metamorphoses can never have wings. This is what occurs in all those insects, such as the lice, spring-tails, and lepismæ, which leave the egg fully formed, and only increase in size afterwards. These are purely oviparous animals, and their development is effected by a series of simple transformations; they never reach the condition of the perfect insect, and as regards external characters, they remain larvæ to the end of their lives.

continents, and engender plague or typhus by the putrefaction of their bodies, after they have produced famine by their voracity. Although these large orthoptera measure nearly ten centimètres om wing to wing, single individuals cannot undertake long journeys. The flight of an isolated insect is heavy, and moreover is never sustained for any length of time. It is in great part the wind which drives these living clouds to such immense distances, occasionally carrying them out to sea.

CHAPTER IX.

METAMORPHOSES OF BATRACHIA AND LAMPREYS.

In treating of insects, we entered, as was necessary, into some detail. Their metamorphoses form, as it were, a key to the study of these phenomena generally. Besides, the terms caterpillar, chrysalis, butterfly, worm, beetle, and grasshopper, recall to our readers' minds certain familiar objects. Whilst following us through this land of wonders, readers have been meeting old acquaintances; and thanks to these, it is hoped that they have grasped the anatomical facts and physiological generalizations, which are more foreign to their usual occupations than the other portion of our remarks. We must now retrace our steps, and from the same point of view explore the whole animal kingdom. Consequently we must enter regions much less known to the general reader. In order that we may be easily understood, we shall be brief, and shall henceforth confine ourselves to pointing out those important facts from which general conclusions may be drawn.

In the very outset we come upon a group with which every one is acquainted, and which deserves special attention, from the fact that for a long while it had been considered as the only vertebrate class exhibiting metamorphoses. We allude to Batrachia, including frogs, land and water newts, and the

kindred genera. In this group we meet with both complete and incomplete metamorphoses; but here we find them marked by quite different features from those we saw among insects. The changes do not appear to take place suddenly, nor is there anything like the apparently torpid condition of the pupa. All the transformations take place gradually, and as far as the external organs are concerned, the development may be closely watched by the observer.

The development of frogs presents another curious phenomenon quite different from what we have already seen. It is this: the young animal, after it has left the egg, and before it has become a larva, is still in a semi-embryonic condition. At this period the digestive tube and its appendages are exceedingly rudimentary. The greater portion of the body is filled by a large mass of yolk or vitellus, inclosed by the skin, which has been formed for some time; and it is at the expense of this alimentary matter that the development proceeds.

The external characters are in keeping with the imperfect condition of the animal at this period. The head is large, and appears to be divided in two on the under surface, each half being prolonged as a sort of process by which the animal attaches itself to surrounding objects; as yet there are no traces of either eyes, nostrils, respiratory or auditory organs; and the belly, of an oblong form, is continued posteriorly as a short tail bordered with a riband-like membrane. This primitive condition, however, does not last long. About the fourth day after birth, the head, which is now as long as the body, has somewhat the appearance of a thimble; the mouth is provided

with a pair of soft lips; the nostrils, eyes, and auditory apparatus have made their appearance; the head is separated by a deep groove from the belly, which has assumed a spherical form, and from which spring a pair of opercula, clothed with little branching gills; and the tail has grown so much that it is now quite as large as the body. The mouth is very soon armed with a horny beak, capable of dividing the vegetable food; the intestine, which is now very long, becomes more fully formed, and assumes a spiral arrangement; the tail is elongated and widened, and the little creature is then called a *tadpole*.

At this period, one of those alterations occurs which are so intimately associated with the ideas we are endeavouring to convey, that we must not pass them by in silence. Our larva first breathed by its skin alone, and afterwards by a pair of little branching gills attached to the opercula. About the seventh or eighth day, however, the opercula are gradually soldered to the abdomen, and the gills fade away and disappear. At the same time a set of new and more complex branchia are developed, in chambers situate on either side of the neck. The new gills are arranged in tufts attached to a solid framework of four cartilaginous arches, and are about a hundred and twelve in number for each side of the body. Here we see a rapid substitution of one organ for another, though both discharge their functions in the same manner, inasmuch as the respiration is just as aquatic in character after the alteration as it was before it.

But the modifications of the respiratory apparatus do not cease here. Before the tadpole can become a frog, it must do away with these second gills and

replace them by lungs; and at the necessary time, a set of changes takes place analogous to those we have already described. The vascular tufts are atrophied, and the lungs, which till now were solid and rudimentary, open up and increase in size. The circulatory organs are correspondingly modified. The calibre of the large branchial vessels is diminished, and the pulmonary trunks increase in number and diameter. Later on, the solid parts of the branchial apparatus disappear also, the bones and cartilages being gradually reabsorbed. Eventually the alteration is fully accomplished, and there remains not the slightest trace of the former branchial apparatus. In this instance, not only has there been transformation and substitution, but an actual metamorphosis has occurred; for the respiration, which was aquatic before, has become atmospheric, and, strictly speaking, the animal from having been a fish has been converted into a batrachian.

If we examine any particular apparatus, we shall find it also presenting many curious phenomena in the course of its development. We shall find that as the herbivorous habits give place to carnivorous ones, the digestive apparatus undergoes a change adapting it to the new form of diet. The mouth increases in size and gape; the little beak-organs, or more correctly, the horny lips, are replaced by teeth, which are attached to the palatine arch, and not to the jaw; the intestine, which before was long and almost cylindrical, becomes shorter, and is inflated in certain portions of its length; and the abdomen, which had been almost spherical, becomes thin and slender. The metamorphosis may now be seen in its entire

extent, and more distinctly as regards the locomotive system than any other. We wish we could give the reader the details of this subject just as they have been given by A. Dugès, but the character of this work forbids our going beyond generalizations.*

The tadpole at first exhibits no trace of either internal or external limbs. It swims about like a fish by the action of its tail,† which is an extensive organ, longer and wider than the body, supported by a prolongation of the vertebral column, moved by powerful muscles, and supplied with large blood-vessels and numerous nervous branches. Beneath the skin and muscles of the anterior and posterior regions of the body two little projections appear at a certain period. These are the limbs, and are at first attached to the adjacent structures by the nerves and blood-vessels which are supplied to them. These projections increase in size, their appendages appear in due course, and eventually the hip and shoulder bones are developed. As soon as these locomotive organs enter upon the discharge of their functions, the tail begins to disappear. Its skin, muscles, nerves, bones, and blood-vessels atrophy, and vanish from our sight.

* "Recherches sur l'Ostéologie et la Myologie des Batrachiens à leurs différentes âges," 1834. This work, which is from the pen of one who was prematurely removed from among us, obtained the physiological prize awarded by the Académie des Sciences.

† Fishes' fins seem rather to guide them when swimming than to aid directly in producing motion. At most they are employed in the latter capacity when the movements are very slow, and are also of use in stopping progression. It is the tail alone which urges forward the fish with rapidity. We may easily be convinced of the truth of this statement by watching the movements of gold-fish in an aquarium.

They have not faded away, they have not simply fallen off, they have not been cast off by a species of moulting, as in the case of insect larvæ. They have been got rid by none of these methods; their substance has been re-absorbed, atom by atom; and hence, although it has ceased to exist, it is not the less alive on that account.

We see then that frogs undergo complete metamorphoses, not only in regard to their entire organism, but as to each set of apparatus, with the exception of the nervous system. The salamanders are not similarly situated. These maintain their external gills throughout the entire larval period, and never acquire internal branchiæ. When reaching the air-breathing condition, they skip, as it were, one of the transformations which frogs undergo. The salamanders have also four legs in the perfect state; but then, in addition to these, they preserve the tail.

The metamorphoses become simpler and simpler as we approach the lower grades of this peculiar class. The Proteus, which is found only in the subterranean lakes of Carniola, and the Axolotl, which inhabits the lakes in the interior of Mexico, retain the gills all through life, and as they possess lungs also, they can breathe by air or water indifferently,—they are really amphibious animals. Finally the Lepidosiren, that type of transitional beings, presents even in the adult state, and in regard to its circulatory and other apparatus, such a combination of the essential characters of reptiles and fishes, that the most skilled of living anatomists are divided as to its true position, and are unable to say to which of the two classes this really paradoxical creature belongs.

Until the year 1856 it was thought by all naturalists that batrachia were the only vertebrate beings which underwent metamorphoses. It was M. Auguste Müller who first proved that phenomena exceedingly like those we have described may also take place in fishes. This naturalist has proved beyond all doubt that the Ammocetidæ are nothing less than the larvæ of the lampreys. However, in reaching their perfect state, they have a much shorter distance to travel than the tadpoles. In their case, both larva and adult breathe by branchial organs; the ammocetis is in reality as much a fish as the lamprey. The only apparatus which undergo a decided modification are, the mouth, which is converted into a sucking and chewing organ, the anterior portions of the digestive tube, which are connected with the orifice of the mouth, and the series of bones and muscles associated with the respiratory function.* If these changes took place in the egg, instead of in the animal leading an independent existence, we should simply term them transformations; but as they are accomplished after the animal has left the egg, they belong to that series of phenomena collectively styled metamorphoses.

* "Ueber die Entwickelung der Neunaugen."—Müller's Archives, 1856. The ammocetis had been considered almost the lowest form of fish, until this great discovery of M. Auguste Müller. The amphioxus, which is a still more aberrant fish, and which approaches in some respects certain annelides (Dorsibranchiata), was, and is still, regarded as the lowest member of the class Pisces. But we are now justified in asking whether such an exceptional creature as the amphioxus is a *perfect* animal. There are many features in its organization which remind one of the common river ammocetes. May it not be the larva of Petromyzon marinus, or of some other species ?

CHAPTER X.

METAMORPHOSES OF MYRIAPODS, CRUSTACEA, AND ANNELIDS.

We shall now return to the invertebrata. The sub-kingdom Annulosa contains, besides the insects, the Myriapoda or Centipedes (Scolopendra Iulus, &c.), Arachnida (spiders and scorpions), and Crustacea (crabs, crayfish, wood-lice, &c.). Of these three classes, the second undergoes no metamorphosis; but the first and third exhibit this phenomenon, and though not as generally as insects, yet occasionally with characters that we have not met with among the latter.

The Iulidæ have been the most fully investigated of all the Myriapoda which undergo metamorphoses; and among those who have devoted attention to them we may mention De Geer, Savi, Waga, and Gervais. When in the adult condition, these animals are composed of a series of segments placed end to end like the beads in a chaplet, of which nearly every segment is provided with two pairs of limbs. These limbs vary in number from 140 to 200, according to the species. When the Iulus first leaves the egg, its body is quite smooth and devoid of legs. After a short time it becomes divided into a number of separate segments, and three pairs of legs are, as it were, pushed out. As the animal grows older and goes

through its successive moultings, the number of segments and legs increases, without the other characters being at all altered. When first hatched, our little iulus is blind, but the eyes make their appearance shortly after the locomotive organs, and increase in number with the growth of the animal. We see that in this instance there is no *real* metamorphosis, the organism being completed, first by the addition of new structures, and then by the repetition of existing ones.

The Crustacea furnish us with similar phenomena. In the little fresh-water prawn and in *Caridina Desmarestii* M. Joly observed that certain thoracic and abdominal feet, and even the branchiæ of the stomachal pieces, do not exhibit themselves till after the animal leaves the egg.* Moreover, of the organs which already exist, some are modified, whilst others, such as the appendages of certain feet, are atrophied. We see that even here there is an approach to metamorphosis in the ordinary acceptation of the term; but on leaving this great section *Macrura*,† and passing on to the *Brachyura*, ‡ we shall find the phenomenon even better marked.

Is there any one of our readers who has spent a

* "Études sur les Mœurs, le Développement et les Métamorphoses d'une petite Salicoque, d'eau douce."—Annales des Sciences naturelles, 1843.

† Literally, long-tailed. To this division of crustacea belong the lobsters, crayfish, shrimps, &c.; in fact, all crustacea whose abdomen, commonly called the tail, is large, well-developed, and is employed in swimming.

‡ Literally, short-tailed. This group includes all crabs and crustacea whose abdomens are slightly developed, curved forwards, and applied against the thorax, which is usually regarded as the body of these animals.

few hours on the sea-shore during low-water? If so he must have observed the little *Portunus mœnas*, "le crabe enragé," as our sailors call it, which of all its tribe leaves its native element the most willingly, and being little sought after, on account of the insipid character of its flesh, brings forth its young in the very neighbourhood of the fishermen's cottages. In its earlier days, and before it assumed this amphibious sort of life, it swam about in the open sea under the form of a Zoë.* Its head was then indistinct from the thorax, both being covered by a sort of globular carapace, from which long processes projected anteriorly, posteriorly, and laterally; its long abdomen terminated in a wide deeply bifurcated extremity; its mouth was of the simplest form; its limbs, which in the adult are complex, and are partly employed in mastication, were represented by four long double oar-like filaments, and its true feet were entirely rudimentary. In fact there was not a single feature to remind one of the flattened greenish crab, which is so regardless of the observer that it hardly troubles itself to run away from him, and which seems in its jerking sidelong gait to imitate the little impish boys of the streets of Paris.

* The larvæ of certain crustacea had been named and classified as distinct species, until Thompson, and afterwards Captain Ducasse, described the strange metamorphoses which these animals undergo. —("Zoological Researches and Illustrations," 1831; "On the double Metamorphosis in the decapodous Crustacea," 1835.—Philosophical Transactions.) In the Zoë group were ranged the larvæ of Brachyura and of some others, which the discoveries of the English naturalists have done away with. Facts of this sort are abundant enough nowadays; and it has been recently shown by Messrs. Coste and Gerbe, that the Phyllosomidæ are only the larvæ of the lobster.

Among the other crustacean orders, and especially among *Entomostraca,* we find an immense number of species which undergo more or less complete metamorphoses. There is still much work to be done in the great field opened by Ducasse and Thompson; but even now we may confidently assert that the species of crustacea which assume the perfect form on emerging from the egg are probably in the minority. It would be idle and indeed impossible to enter into further details without the assistance of numerous engravings. Besides, we should really be travelling on ground we have already gone over; we should only find what we have already observed; viz. the creation of new structures, and the destruction, modification, and increase of others. We find almost invariably, that the final result of metamorphosis is the progressive completion and elevation of the organism.

We see quite an opposite state of things in two very curious secondary groups of this class Crustacea. Here, to judge from appearances, metamorphosis degrades the creature instead of elevating it, and modifies the organism in such an unusual manner that one is puzzled to know whether the animal is not an abnormal one. Cuvier died in the belief that the Balænidæ and Anatifera were mollusks, and that the Lerneæ were intestinal worms.

It was Messrs. Thompson and Nordmann who first corrected this double error. The former discovered the true nature of the Cirrhipedia,* the latter that of

* "Zoological Researches and Illustrations; or, Natural History of Nondescript or imperfectly-known Animals," 1831.

the Siphonostomidæ.* In both cases the truth was arrived at by examining the animals as they emerged from the egg, by contrasting them with larvæ known to belong with certainty to other crustacea, and by watching closely their various transformations. When the results of these researches were first published, they were received with some scepticism, but having been confirmed by numerous observers, they are now unquestionable, and no one can deny these naturalists the honour of having been the first to reveal that curious mode of evolution, which we have termed *recurrent development*.†

Uniting the observations of Darwin and his rivals, we shall endeavour to describe the metamorphoses of one of these Balænidæ, whose pointed, jagged shells cover the rocks most exposed to the waves with a sort of crust.

From the egg laid by the mother there springs an almost microscopic larva, whose narrow body is divided

* "Micrographische Beitrage zur Naturgeschichte der wirbellosen Thiere," 1832.

† Among those who have added to the history of the development of Cirrhipedia, I may mention the names of Bate, Burmeister, and Goodsir, and especially that of Mr. Darwin, who has written a most valuable work upon the entire group,—"A Monograph of the Sub-class Cirrhipedia,"—Publications of the Ray Society, 1854. Three French naturalists also devoted themselves to this subject—M. Souleyet who died when engaged in his researches; M. Bouchard-Chantereaux, known by his works on mollusks; and M. Hesse, Commissaire de la marine. Of works on the Siphonostomidæ, I may refer to the valuable memoir of M. Van Beneden, in which he brings together the researches of his predecessors and the results of his own numerous and persevering investigations ("Annales des Sciences naturelles," 1831), and the several communications which he has since made to the "Mémoires" and "Bulletins" of the Academy of Brussels.

into a few long segments, and carries anteriorly two free antennæ, and laterally two other appendages of a similar nature inclosed in horny cases. Three pairs of feet clothed with long stout hairs answer the purpose of oars. A carapace, composed of a single piece, covers the back, and laps over the body anteriorly and laterally, disclosing a single solitary eye in front. The little balænus being thus provided with sense-organs and locomotive apparatus, swims rapidly through the water, reminding us forcibly of the larva of a cyclops.*

A change is now undergone, and the creature resembles a cypris or an adult limnadia.† Its body is entirely concealed by a pair of valves like those of acephalous mollusks;‡ the number of feet increases; and by the aid of two anterior appendages, which spring from the shell, it is enabled to attach itself to seaweeds and other submarine bodies. It is by grasping the rock with these peculiar organs that the little crustacean fixes itself in some position where the waves beat most violently; it then loses its bivalve shell, and replaces it by several distinct pieces, which, like so many plates, cover the back and sides of the animal. This, however, is essentially a transitory condition. A sort of calcareous wall is very soon raised around this species of nymph, and assumes the form of an irregular hollow pyramid, with a wide and

* The Cyclops is a small crustacean of an inferior order, which is common enough in certain fresh-water ponds, &c., and which also undergoes metamorphoses that have been known for a long while.

† The Cypris and Limnadia are small fresh-water crustacea also.

‡ The oysters, scallops, mussels, &c.; in fact all mollusks whose shell is composed of two valves united by a hinge, belong to this group, of which we shall say more hereafter.

jagged orifice. It is in this prison that the young balænus, hitherto free and unrestrained, is confined for the rest of its days. It is folded in two; and its feet, henceforth useless as fins, are transformed into recurved and beautifully ciliated cirrhi. It is these latter which, when moved by powerful muscles, henceforth provide our little monk with food. They form a sort of double plume above the head, projecting beyond the opening of the valves, and when rapidly moved backwards and forwards, they draw to its mouth the food which the balænus cannot now go in pursuit of.

The modifications which metamorphosis brings about, extend beyond mere form and structure. Very important functional changes are also effected by it. It is only when the balænus is thus imprisoned and deformed, when it is blind and can no longer move from place to place, that its reproductive organs are developed. Here is an instance of an animal which when in its nymph and larval state is, as regards the possession of the essential characters of an animal, a higher being than when it assumes the adult form; but in neither of the former conditions can it be a parent. The progress of development has degraded it in the animal scale; but whilst this progress has made all the functions but one subordinate to that of nutrition, it has been the means of producing the apparatus which insures the continuance of the species.

The result of recurrent development seems in many cases to be the sacrifice of all other functions to that of reproduction. This final object is even still more apparent in the lower crustacea, and especially among

the Lerneæ, or *fish-lice,* as they are termed, than in the Cirrhipedia. Among the Lerneæ the degradation of the being extends much further than we should imagine possible.

The young lernea is a genuine crustacean when it emerges from the egg. At first it is like a cyclops larva; it has eyes, and swims freely about by the aid of two feet, each of which ends in a large bunch of filaments. During the second period of its existence, it has three pairs of feet in front, and as these are provided with hooked claws, they are equally well adapted to assist in locomotion or to grasp the smooth skin and gills of fishes. At this period, moreover, it acquires four posterior swimming feet, and a tail or abdomen like that of other crustacea. Up to this, metamorphosis was elevating the being more and more; it now begins to destroy what it has constructed.

In assuming the adult condition, the female grows to an immense size; two of her anterior appendages become more developed, curved in a semicircular manner, and united by their extremities, which terminate in a sort of projection, are plunged into the tissues of the animal upon which she is parasitic, and then fastened there permanently; two others, reduced to mere hooklets, attach in a similar manner the mouth, which is converted into a sucking organ; the remaining appendages disappear, and the body, inflated and deformed, is now but an irregularly-shaped pouch, containing a stomach and a quantity of ova. At the same time the male, disfigured to a lesser extent, but still two or three hundred times smaller than the female, attaches himself to the body of his

spouse, and seems to live upon her juices just as she does upon those of the fish. In both, the locomotive and sense organs have disappeared; and as the two lead a purely vegetative existence, they may fairly be regarded as mere reproductive machines.

We shall now leave the Articulata and pass on to the Annuloïda or worms, which with the former constitute the sub-kingdom *Annulosa*. The first are purely oviparous animals; the second present in a well-marked manner the phenomena of geneagenesis, which we shall examine in another chapter. In reality, the class Annelida is the only one which presents phenomena of the kind we are now alluding to. In a work to which perhaps I have already alluded too often,* I described, at length, the metamorphoses of Terebella according to the investigations of M. Edwards, and those of Hermella according to my own researches. Here, I shall limit myself to stating that in these creatures also the organism is considerably altered in proportion as the mode of life differs from what it has been heretofore. These animals, which are at first of an erratic character, afterwards become sedentary, and are inclosed in tubes which they never leave. In one respect this is a step backwards; for locomotion is one of the most characteristic attributes of the animal, which, when deprived of it, is injured to a certain extent. But although, from this point of view, Hermella and Terebella are degraded by the progress of development, they are elevated in other respects, and on the whole gain rather than lose by the alteration. In this instance metamorphosis exhibits itself in an

* "Souvenirs d'un Naturaliste."

entirely new light, inasmuch as it tends at the same time to elevate and degrade an animal in the zoological series. Hereafter we shall find several examples of this double action; consequently, we shall see the animal in its perfect condition, placed sometimes above, and at others below its larval state, according as one or other of these opposite tendencies has the upper hand.

CHAPTER XI.

METAMORPHOSES OF GASTROPODOUS AND ACEPHALOUS MOLLUSKS.

The discovery of metamorphoses among mollusks is quite a modern one, and there are doubtless very many more discoveries to be made in this branch of science. In the year 1832, the celebrated German anatomist Carus described for the first time the larvæ of Anadonta, a sort of fresh-water mussel, which is abundant in all the canals and ponds throughout Europe.* But as always occurs in such cases, the facts, being quite unexpected, were at first denied. It was asserted that the larvæ were only parasites, which existed in great numbers in the gills of mollusks. They were given a distinct name, and this erroneous interpretation having had the authority of Carus's opponents Rathke and Jacobson, became generally accepted.

At this period, whilst modestly pursuing the practice of medicine, and having, if anything, too much time upon my hands, I devoted myself to natural history when waiting for patients. In ignorance of the labours of my distinguished contemporaries, I pursued the same subject. I watched the development of the anadonta's eggs daily, during at least five months, from the time they were deposited, until an accident

* Carus's memoir appeared in the "Nova Acta Naturæ Curiosorum."

occurred which destroyed the whole brood. I had seen enough, however; and I believe I may say, that from the publication of my researches and of M. de Blainville's report, the metamorphosis of mollusks became an established fact.* Other investigations have since been made. From an examination of all these works, we are justified in concluding that metamorphosis occurs, in the entire group as well as in the classes it comprises, and that it is in some instances complete, in others incomplete, and occasionally entirely absent.

Of all classes of mollusks, the most fully investigated from a development point of view is that of gastropods, including such animals as the snail and slug. Both these are air-breathing mollusks, and simply oviparous; and those which inhabit fresh water bring forth their young in a somewhat similar manner.† Marine species, on the other hand, undergo true metamorphoses. Let us see, for example, what takes place in one of those *phlebenterate* mollusks which have subjected me to so many severe controversial attacks.‡ These animals

* This report was read before the French Academy in 1835, and had been prepared by a commission, consisting of Messrs. Geoffroy Saint-Hilaire, F. Cuvier, and De Blainville. Perhaps the reader may imagine that I allude too frequently to my own researches, but I trust he will appreciate and excuse the feeling by which I am actuated in thus referring to my earliest contribution to science.

† *Neritina fluviatilis* is an exception; the larvæ of this mollusk are exceedingly like those described and figured in M. Ed. Claparede's beautiful work "Anatomie und Entwickelungsgeschichte der fluviatilis Neritina."—Müller's Archives, 1857.

‡ When first I published my researches on phlebenterate mollusks, and asserted that these animals have no distinct *veins*, I was opposed by nearly every naturalist who had paid attention to the subject. I think I may safely say that at present it is just the reverse.

have no shell, even in the adult condition; their head is provided with four long stout horns or tentacles, at whose base a single pair of eyes may be seen; and their back is covered with little projections, which for a long while had been considered simple branchiæ. They crawl along the bottom of the sea, by means of a thick fleshy disk, which is called a foot. These pretty little creatures are most brilliantly coloured, and look as if they were composed of enamel and crystal. So much for their external characters. In the interior we find, besides other organs, a stomach, which terminates in an exceedingly short intestine, and gives off from its opposite side a series of more or less numerous canals, which ramify, and send prolongations almost to the extremities of the dorsal appendages. The liver, which is usually so extensive in mollusks, is here represented by delicate glandular layers which surround the terminal cœca of the gastro-vascular apparatus. Let us see what these exceptional mollusks are like in their earliest stages. On emerging from the egg, each larva is provided with a shell, and its foot, rudimentary as yet, has a sort of horny plate attached to it, which it raises or lowers like a drawbridge when it wishes to close or open its shell. Being unable to creep along, it is furnished with a locomotive organ, in the form of a large double collar placed above the mouth. The edges of this structure are clothed with long vibratile cilia, which make it a very powerful swimming organ, that the animal folds or unfolds at will, when retreating into its shell. The animal, surrounded by the latter, and fixed to it by a set of strong muscles, possesses a digestive apparatus and liver like those of other mollusks. After a certain

length of time, however, the adherent muscles become detached, and the animal leaves the dwelling which it inhabited since its birth; its body is elongated; the foot having cast off its operculum, which is now useless, begins to discharge its real function, and on the other hand, the rotatory apparatus becomes atrophied; the stomach is prolonged backwards as a cul-de-sac, which rapidly increases in size, and sends off ramifications; a pair of appendages is seen upon the dorsal surface: these are soon followed by others, and eventually the larva, which at first resembled that of an ordinary mollusk, becomes a true *phlebenterate*.

The embryogeny of gastropods has been the subject of several works; and among those who have helped to clear up that branch which we are considering, we find the names of some of our most distinguished contemporaries;* but it is not the same with the Acephala or *bivalve* mollusks. The only researches upon this subject, in addition to those already mentioned, are, so far as I am aware, Loeven's great work, some essays

* The first researches upon the development of gastropods are those of M. Stiebel, a German naturalist, and are dated 1815. Among those who have since devoted themselves to the subject, I may mention the names of Allman, W. B. Carpenter, Carus, Danielsen, Dumortier, Frey, Grant, Jacquemin, Koren, Klark, Lacaze du Thiers, Laurent, Leydig, F. Müller, Loeven, Nordmann, Pouchet, Prévost, Rathke, Reid, Saars, Von Siebold, Van Beneden, Vogt, Windischmann, &c. The earlier writings of these naturalists were devoted to the terrestrial and fresh-water species, and consequently the metamorphoses of the marine classes remained for a long while unknown. In 1827, the English naturalist Grant discovered the rotatory apparatus and pointed out its function; but it was not until the year 1837 that M. Saars, a clergyman of Berghem, made known the important fact that the larvæ of naked mollusks are provided with a distinct shell.

on the development of oysters,* my own memoir on the embryogeny of teredo, and the beautiful researches of M. Lacaze du Thiers upon that of *dentalium*.† It is in the latter that the most complex metamorphoses are observed; these phenomena are of a far simpler nature in the oyster, are still more so in the anodon, and are entirely absent in other small bivalve mollusks, which inhabit fresh-water ponds and lakes. The larvæ of all the marine members of this group present at first the ciliated form, and are naked; but shortly afterwards they are furnished with a shell, and with a rotatory apparatus, like that of gastropods. This organ may be drawn within or extended beyond the shell, at the desire of the animal, which is in addition provided with a foot, which is occasionally very long, and movable. By the assistance of the latter, the creature can either crawl along the sea-bottom or swim through the water, although at a later date it may be soldered to a rock, like the oyster, or fixed immovably to the chamber it has constructed, like the *teredo*.

* Written by M. Davaine, and called "Recherches sur la Réproduction des Huîtres." These memoirs obtained the Academy's prize for experimental physiology in 1855, and some of their results have since been corrected by M. Lacaze du Thiers.

† M. Lacaze du Thiers published a monograph on this peculiar animal, and it is unquestionably the most complete work which has ever been written upon a single mollusk ("Histoire de l'Organisation, du Développement, des Mœurs et des Rapports zoologiques du Dentale"). I am sorry that I cannot give some of the details of this creature's history; but on account of its very exceptional character, it does not come within the limits of my present scheme. I may, however, state that, at a certain period of its life the larva of dentalium is so like that of an annelid that it may be mistaken for one, and that its shell, although symmetrical at first, is always univalve.

The young *anodon* has none of these organs; but to compensate for their absence, it possesses a very peculiar apparatus for closing its shell and preventing the entrance of parasitic infusoria. Each valve, which is then of a triangular form, has attached to its upper portion a long flexible structure, and this latter is covered with strong teeth, which are arranged in squares of five each—four forming the sides, and one in the centre. By means of muscles for the purpose, these two structures can be drawn inwards, somewhat in the way in which a knife turns in its handle; and the teeth being thus firmly clenched, the shell is as securely closed as if it were done by machinery.

The larvæ of oysters, teredos, and anodons are retained, either in the gills or mouth of the parent, from the time they leave the egg till the moment of their metamorphosis; they then lose their temporary organs and assume the adult features, being sometimes elevated a few degrees in the animal scale, at others descending to a lower grade than they occupied as larvæ. The former takes place in the case of the anodons, which acquire a foot, and can at all events crawl along the mud; the latter among oysters; and, still more so, among teredos. The latter, which were the most highly organized of the three groups when in the larval state, are by far the most degraded in the adult condition.

Thus we see, that even among Acephala, the two forms of metamorphoses are presented, and that in some instances the development elevates the being, as in the case of insects; in others, it is as recurrent, as in the Cirrhipedia and Lerneæ.

CHAPTER XII.

NATURE, CAUSES, AND PROCESSES OF METAMORPHOSES.—CONCLUSION.

The general conceptions as to the nature of metamorphosis have always varied with the ruling philosophic doctrines of the time. Some of the facts we have already pointed out were at one period brought forward to support the theory of spontaneous generation, of which we shall see more hereafter. And when, by a natural reaction, the hypothesis of evolution was announced, and, owing to the superiority of those who supported it, was almost universally accepted, these same facts and many others were employed in its defence.

For example, according to Réaumur, there is no such thing as real production; development is the only phenomenon he recognized. Plants and animals which to us appear to be newly formed, have always existed, but only appear when circumstances admit of their growing sufficiently large to be recognized by our senses. What is true of the whole is true of its parts; consequently the metamorphoses of an insect are only apparent. According to this doctrine, the butterfly, which flies from flower to flower, has lived since the creation of the world, and has possessed all its organs, wings, proboscis, feet, scales, etc. The chrysalis and caterpillar inclose it, and are, as

Harvey stated, genuine ova, included one within the other. Curious ova, certainly, possessing limbs, a mouth, and digestive apparatus, which are destined for the locomotion, defence, and nutrition of the real animal: eggs, which chew, grind, and digest food as the mother does that which supplies the fœtus. Thus protected, and nourished by the animal apparatus which surrounds it, the butterfly exhibits no outward traces of infancy; when the proper time arrives, it throws off this *organized garb*, which is no longer required, and would, in fact, inconvenience it, and, devoid of all disguise, it now exhibits itself in its real character, being only altered as to its size, which is greater than before.* These are some of the inextricable difficulties into which the supporters of the evolution theory were led, despite their high character for intelligence.

Notwithstanding the errors which these preconceived ideas gave rise to, Réaumur perceived and appreciated a very important fact. He looked upon the butterfly in the caterpillar state as an infant. He should have said an embryo. The infant in being converted into an adult is only increased in size and developed; but the caterpillar has quite a different part to play in assuming the butterfly form. In the metamorphoses it undergoes in approaching its perfect state, we are reminded of the embryogenic phenomena we spoke of in an earlier chapter. We see them during the entire larval stage, for the caterpillar possesses many of these temporary organs, whose

* "Mémoires pour servir à l'Histoire des Insectes." These views are very distinctly stated in the eighth memoir of vol. i.; I have almost transcribed the author's own remarks.

existence shows us that the animal is on the road to a final perfect condition; we see them with increased vital activity before the first transformation, and for some time after it. It is indeed a critical period, not only for insects in general, but for butterflies in particular, in which the animal is, so to speak, re-cast and constructed upon a very different plan from that which was adopted before. It would be idle to dwell upon this fact; let the reader turn, instead, to the earlier pages of this work; or, better still, to Herold's and Newport's beautiful illustrations. In glancing even at the changes undergone by the nervous system, and in watching the re-alteration and development of the ganglia from hour to hour, we are reminded of that period in the transformations of the mammalian embryo when the most intense and energetic action was taking place.

The insect whilst in the larval condition has only to increase in size, like the infant to which Réaumur compared it. But even from this point of view it exhibits a decidedly embryogenic character, viz., *the rapidity of this growth.* In fact, it is the common rule among all viviparous animals that the increase in weight and volume, which at first takes place with rapidity, becomes less marked as the organism approaches its perfect form. The human embryo, which is quite distinct about the third week after impregnation, measures at this time 6·75 millimètres in length, and weighs about 12 centigrammes. About the eighth week, or, in other words, thirty-five days after the above-mentioned period, it is 20 millimètres long, and weighs 216 centigrammes. About the fourth month, when it may almost be called a fœtus, it

measures 20 centimètres in length, and has attained a weight of 224 grammes. In the course of four months, then, it has become thirty times as long and eighteen hundred times as heavy as it was when we first examined it. From this time forward it grows about an inch, or nearly three centimètres, every fifteen days; till, at the time of its birth, it has attained a length of nearly half a mètre, and a weight of about three and a half kilogrammes.* Thus we see that in less than nine months the human embryo has become, in round numbers, seventy times longer and twenty-nine times heavier than it was when three weeks old.

Among insects we find an analogous state of things. According to Rédi, the larva of a meat-fly (*Musca carnaria*) becomes, in the short space of twenty-four hours, from a hundred and forty to two hundred times heavier than it was before.† Lyonnet has shown, by direct observation, and by calculation, that the caterpillar we spoke of before (*Cossus ligniperda*) is *seventy-two thousand* times heavier in the chrysalis condition than when it emerged from the egg.

Insects do not generally increase in size as they reach the perfect condition, but, on the contrary, are very much smaller than when in the larval state. This decrease in size is particularly well marked in the *Stratiomydæ*, whose history we have given in another chapter; but these insects may be regarded as excep-

* In giving these dimensions of the embryo at different periods of its existence, I have quoted the figures of Olivier and Chaussier, whose results were arrived at by an examination of fifteen thousand specimens.—Dictionnaire de Médecine.

† "Introduction à l'Entomologie," by Th. Lacordaire.

tions to the general rule. Animals which undergo metamorphoses, almost always grow after birth, just as in the case of man. Many of them are like certain oviparа, and grow during the whole of their lives. Hence it is not surprising that the differences of weight and volume between young and old individuals should be greater than it is among vivipara. At the age of twenty, man is rarely four times as long as the newborn infant; and his average weight is hardly thirty times greater. The Teredo larva, which is about to undergo a change of form, is four thousand times larger than when it sprung from the egg, and is still many million times smaller than its mother.*

There is another fact of a more decisive nature which shows the embryonic character of the larva. We saw in an earlier chapter that every monstrosity is congenital, and is referable to a period when the embryonic development is going on. We have frequently seen monster insects. Instances of hermaphrodite insects are common enough in entomological collections, for amateurs carefully preserve these interesting specimens instead of delivering them to the anatomist's scalpel. Sometimes, however, we meet with persons actuated by a more truly scientific spirit: it was in this way that Rudolphi was enabled to dis-

* Indefinite growth during the entire life of the individual is met with only among the lower species of the superior animals. Thus, among vertebrates this peculiarity is presented only by certain fishes and reptiles. In these even, the growth slackens considerably as life is prolonged: we may observe this occasionally in the carp. I once saw one of these fish which was said to have been transmitted in a fisherman's family, from father to son, for more than a hundred years. It was hardly longer than an ordinary carp, but was much thicker.

sect a specimen which had the external marks of both sexes, and to prove that its internal characters were equally monstrous; thus showing that a moth exhibited one of those anomalies rarest among vertebrated animals.

Among insects as among vertebrates we meet with monstrous limbs. Several observers have described the double and triple legs of beetles, just as Meckel saw similar organs in the drake, and M. Geoffroy in the sheep.

It is questionable whether the foregoing monstrosities are really referable to that period of the animal's life immediately after its emergence from the egg. In fact, there is nothing to oppose the view that they have occurred whilst development was going on *within* the ovum; but we cannot say the same of the following ones. The larva does not possess antennæ, and yet we have seen beetles with more than the usual number of these organs. Stannius described a neuter bee, which, like certain forms of the human fœtus, fully realized the fable of the Cyclops: its two compound eyes were fused together, constituting a single ocular mass, which was situated almost on the top of the creature's head. In these two cases we can point to the period when the labour of natural development was interrupted. It was about the period of the last month, when the larva was preparing to assume the nymph form, that the disturbing cause affected the course of normal organization.

It is to this period also in the history of development that we must refer a series of monsters whose very forms are the best solution of the problem we are trying to solve. We allude to those insects which

present certain larval characters in their perfect state—such, for example, as the mulberry bombyx (*Bombyx mori*), mentioned by Majoli, whose thorax and abdomen were those of the silkworm; and especially the insect described by J. F. Müller, whose entire body was that of a butterfly, with the addition of a caterpillar's head. In this instance the arrest of development occurred evidently as the animal was passing from the larval to the higher condition.*

We see, therefore, that the larva, nymph, and perfect insect are but one animal, in the same way as the embryo, fœtus, and young mammal are but so many stages of the one individual. Réaumur imagined that the larva and the insect were two distinct beings, and that the first inclosed and supported the second, somewhat in the same manner as the mother carries and supports the *fœtus in utero*. This distinguished observer brought forward the results of both Swammerdam's and his own researches in support of this theory. "If," said he, "you open a caterpillar's skin two or three days before it is converted into a chrysalis, you will perceive the wings, antennæ, and proboscis of the butterfly; and if you cut off one of this caterpillar's scaly feet, the butterfly will be lame."

These facts are, as we said before, quite correct; but where Réaumur has seen evidence in support of the evolution theory, we have found proof of that doctrine of epigenesis which we have seen fully confirmed by the development of mammalia. Réaumur,

* The above examples of insect monstrosities may be found in either Isidore Geoffroy Saint-Hilaire's "L'Histoire des Anomalies de l'Organisation," or M. Lacordaire's "L'Introduction à l'Entomologie."

when obliged to confess that he could not see the characteristic organs of the butterfly in less-advanced caterpillars, attributed their apparent absence to the feebleness of his powers of vision, and the imperfect state of his instruments. Thanks to the means of investigation we possess nowadays, we can assert most positively that the young caterpillar has neither wings, nor antennæ, nor even a proboscis. But at all events we have been shown by our predecessors' observations that none of these organs appear suddenly, that the most abrupt changes have been in progress for a long while, and that in insects, as in all other animals which undergo metamorphoses, their phenomena are gradual and progressive. There is this distinction, however: that which in Mollusks, Worms, Crustacea, and Batrachia takes place openly, is concealed in insects by a veil, which is only removed when everything has been completed. Moreover, in this latter class, the Hemiptera and Orthoptera manifest the same continuity in their metamorphoses which we observed in other instances.

The phenomena associated with the inmost nature of living beings are too far beyond the grasp of human knowledge to admit of our framing even an hypothesis as to the *primary cause* of metamorphoses; but, without outstepping the limits of a fair reserve, we can at least in certain cases conjecture what is the *immediate* cause.

In the earlier pages of this work we contrasted the voluminous vitellus of ovipara with the very small one of vivipara; and we saw how the former was sufficient for the formation and afterwards for the growth of the embryo, whilst the latter could only discharge one of

these functions. We stated, also, that as a consequence of this provision, birds and lizards are completely organized within the isolated egg, whilst, on the contrary, mammals are forced, in order to reach the same condition of development, to remain within the mother's uterus, where they are nourished through the medium of truly temporary organs. Now, as (for a reason which doubtless we shall never be acquainted with) an egg with a small vitellus may be destined to be expelled, there is, nevertheless, a necessity for a mode of existence during the state intermediate between the embryonic and fully-formed animal; and this necessity must be provided for.

This is one of those problems which Nature sets for herself, as it were, for the mere pleasure of solving them—the solution in this instance being found in the phenomenon of metamorphoses. We invariably find, even among species which undergo recurrent metamorphoses, that the embryo which springs from the egg presents a relatively more simple organization than the adult; hence its wants are fewer, and it can satisfy them. Gradually it becomes fully formed, its sphere of activity is enlarged, and finally it assumes its adult characters when it has received the requisite materials from the external world.

The larva, then, is but an embryo leading an independent life, which feeds itself instead of being nourished by the mother, and which undergoes, externally, beneath our very eyes, changes—transformations—which take place, among vivipara, in the depth of the mother's uterus.* In assigning the

* I give, word for word, the substance of an article which may be considered as the first edition of this chapter (1855). M. Cla-

insufficiency of the organizable materials of the vitellus as an approximate cause of the phenomena we have under consideration, we can explain, or rather co-ordinate, facts which, apart from this view, we could not associate together. The greater this insufficiency is, the more imperfect will the embryo be which is formed at the expense of the vitellus, the more removed will it be from its final characters, and the greater must be the supply with which it is furnished in approaching to and attaining them. Observation bears out this conclusion. Insects' eggs are enormous when compared with those of certain mollusks. The egg of *Cossus ligniperda* is about thirty thousand times larger than that of the Teredo. Moreover, the little caterpillar which springs from it is already a very complex animal, or, in other words, a very advanced embryo. The Teredo, on the other hand, is in the first instance as simple as possible. Its body is, so to speak, but a homogeneous pulp, in which a digestive tube is vaguely discernible. The caterpillar will, doubtless, have to form some organs, but more especially to develop and modify those which it has got already: the Teredo will have to acquire all its parts.

We have pointed out the nature, and at least one, of the chief causes of metamorphosis, and of its modifications.* Is it necessary to dwell upon the

parède has expressed the same idea, in summing up the views propounded by Leuckart. These are his words :—"What does metamorphosis consist in ? . . . It is the passage of an animal deprived of its egg-envelope through phases whose object is to bring it to its own or its parent's type, and which among other creatures takes place within the egg itself."

* In 1855 I said reservedly, "It is not my intention to lay down

processes? Who does not see that these phenomena, which are so curious even in the commencement, and which in a general aspect are identical with those of vivipara, and are performed by an entirely similar apparatus, are after all but *transformations?* First, *epigenesis,* and then simple or complex *evolution.* These are the processes we see taking place in every organ which is added to those of the larva, in converting it into an insect, a crustacean, or a perfect reptile. *Formation* is evident; and *modification* and *progressive development* occur beneath our eyes, when we see the external gills and the internal which succeed them and precede the lung in the frog, the dorsal projections which appear in the phlebenterate mollusk, the wings which are pushed out from the thorax of the insect, and the segments which are added to those already existing in the myriapod.

an absolute law, nor to associate the greater or lesser complication of the metamorphoses, *only* with the greater or lesser volume of vitellus. I merely wish to point out *one* cause which has not been taken sufficiently into account, but which is doubtless only one of a series. The period of incubation, for example, may also be regarded as an important element in the inquiry, and as exerting a decided influence. The egg of Hermella and of Teredo is in twelve hours entirely transformed into an animal endowed with the power of voluntary movement. This is, doubtless, another of the principal causes of the extreme simplicity of the larva." I have since become aware—through M. Claparède's work—that Leuckart had attributed metamorphoses to the insufficiency of the plastic elements of the yolk, even before I had done so. I am glad to meet on this point with a naturalist who has given us so many splendid memoirs since that period. But, so far as I can see, I cannot admit with him that it is the *sole* cause of metamorphoses. M. Claparède has already maintained that this conclusion is too absolute, and has, it seems to me, gone too far in the opposite direction. —Bibliothèque Universelle de Genève, *l. c.*

Look at the gradual disappearance of the gills and tail of a tadpole, and of the rotary apparatus of the Teredo, and although you be not a naturalist, you will say, "These are organs which have *atrophied*." Compare the young crab's tail with that of the adult; the reproductive organs of a neuter with those of a queen bee; and you will yourself employ the expression—*arrest of development*.

Observe the feet of the Lernea, at first employed as oars, and afterwards, when converted into a sort of anchor, serving to attach the animal to its living residence, and you will be struck with the manner in which Nature adapts an already existing organ to an entirely new function. You will then perceive that metamorphosis, properly so called, is above all things characterized by transformations.

In order that these phenomena shall take place, it is necessary that the same stream of matter shall flow to and from the parts as that which exists in Mammalia. In the great majority of cases the alterations do not occur suddenly, and they take place, moreover, in the very depth of the tissues. The branchiæ of the tadpole do not fall off directly to give place to the lung; nor does the tail become detached when the limbs are formed. No; in proportion as the one is developed, with its bones, muscles, nerves, and vessels, the other decreases in every portion of its structure and in all its parts simultaneously. The latter is actually resorbed molecule by molecule, just as the former is being built up atom by atom.

It is true that in Insects and Crustacea there is *apparently* a different state of things. At each period of moulting, and during every metamorphosis, the old

skin, or carapace, as the case may be, is cast aside as a useless covering; but this is because of its inflexible nature, owing to the horny and inorganic matter it contains preventing the growth of the animal. Look into the interior of these beings. With Swammerdam, Réaumur, Hérold, and Newport as your guides, follow the series of important changes which the central organs undergo, and you will see that the phenomenon of molecular absorption is present in these creatures also.

Here is a striking example, in addition to those we have already cited. The larva, prior to becoming a chrysalis, stores up, so to speak, the materials requisite for its transformations. Its organs are almost embedded in a peculiar fatty tissue. If, however, you examine the perfect insect, you will not find a trace of this substance. It has been nearly all employed in repairing the organs; and as matter cannot be acted on by the vital force without the production of a certain amount of waste, the intestine (which was empty at the commencement of metamorphosis) is found, when the crisis is over, charged with a quantity of excrementitious matter which was then formed.*

We see, then, that the study of metamorphosis, like that of transformation, carries us forcibly to the point from which we started. We can understand neither one nor the other, unless we admit the existence of a force inherent in all living organisms, ever

* In certain lepidoptera this matter is of a reddish colour. The insect discharges it as it leaves the cocoon, and the spots which are thus left upon walls, stones, branches, etc., in the neighbourhood, are often sufficiently numerous to give rise to the supposition that there has been a shower of blood.

present and ever active, controlling the materials borrowed from the external world, arranging them in accordance with a preconceived plan, and rejecting them when they are not longer fit for use. *Life*, then —the *vital vortex*—we must regard as the first cause, and as the general process of all the phenomena which we have been describing.

CHAPTER XIII.

GENEAGENESIS. — FIRST PHENOMENA OF GENEAGENESIS DISCOVERED IN ANIMALS.—AGAMIC* GENERATION (APHIDES).—REPRODUCTION BY FISSURATION AND BY GEMMATION (POLYPS, HYDRÆ, COMPOUND ASCIDIANS).

In the two earlier portions of this work we saw that the lower animals, and even man himself, spring from germs which are invariably similar at first, and which moreover are genuine ova. I pointed out, also, how, under the influence of vital action, this resemblance disappeared, and there resulted an infinite variety of forms. At the same time I showed that no single species exhibited at the outset its definitive or adult features,—that the embryo is never the miniature of the perfect being. From this the reader has been led to conclude that every animal undergoes metamorphoses. Nevertheless, this phenomenon, although in all important particulars the same, assumes different features in different groups. In man, and in almost all vertebrates, the transformations take place chiefly within the egg, and on that account are familiar only to scientific men. In insects, on the contrary, the true *metamorphoses* occurring external to the egg, and modifying the form of an animal as extensively as if a fish were converted into a bird,

* Without intercourse of the sexes.

have attracted the attention of even ordinary observers.

In a developmental point of view, the histories of man and of the butterfly, although presenting very marked contrasts, yet have some important features in common. In both we find a male and female parent, and offspring which are directly derived from this couple, and which must pass, in reaching their final state, through the same phases as those which characterized their parents. In the vertebrated as in the annulose animal we perceive that the progeny, male and female, resemble the parents, allowing of course for *individual* differences. In all the groups which have engaged our attention up to the present, the individuality of each being is manifest from the first appearance of the germ, and in the first rudiments of the egg, and remains entirely distinct until the being itself ceases to exist. These facts are well known even to vulgar experience, and till lately scientific and unscientific persons agreed in regarding them as the expression of absolute laws.

We must now proceed to consider a set of phenomena as novel as they are remarkable. Here we meet with animals which, strictly speaking, have neither father nor mother, but simply a *single parent*, which produces them *directly* from its own body. We shall meet with sons which never resembled their father, and which produce offspring quite unlike themselves. We shall see a single germ give rise, more or less directly, not to a *single* individual, but to multitudes of individuals, and even occasionally to distinct generations, which are not related either as to form or structure, or mode of life. We shall thus

perceive that the primitive individuality of the germ is lost, and is replaced by a series of new individualities ere the products of this germ reach their final condition.

We are now entering upon a world where the most fundamental laws of the animal kingdom appear as it were reversed. The reader, however, will, I trust, be enabled to conclude that there are no *real* contradictions, and that even in cases so *apparently* exceptional, creative nature displays a wonderful regularity.

In approaching this portion of my task, I feel how great the difficulties are which encompass both my readers and myself. Even without having taken out a course of lectures on anatomy, every one has a vague notion of the position of the heart, lungs, stomach, and liver of mammalia: the external characters of these animals are at all events familiar to all. To speak of their *transformations* is to lead even an enlightened man to a class of ideas and facts with which he is doubtless little familiar, but where he meets at least some points with which he is acquainted. In regard to metamorphoses, properly so called, the Lepidoptera afforded us a sort of type to which we could refer not only the history of other insects, but even in most cases that of Annulosa in general, of Mollusca and Batrachia. In their different groups, too, the various species to which it was necessary to allude are more or less known to every person.

Now, on the contrary, I am about to treat of beings whose form and organization have been studied by naturalists only. The names of the animals will be new, and many of them will seem rude and barbarous. I shall now be obliged to demonstrate everything, for

the precise reason that the phenomena we considered before, become here more strange and complex than ever. I shall, however, attempt the task, which without the assistance of illustrative figures is by no means an easy one.

In the first place, we shall mention the simplest facts bearing upon the subject, and those also which were first observed.

In all the animals previously spoken of, a new generation can be produced only through the intercourse of two individuals of opposite sexes. This fact is so well known that it has been always regarded by the mass as one of the great laws of Nature. The exceptional facts observed in the case of man himself, and perhaps also the fables of the ancients, prepared naturalists for the discovery of certain animals in which the attributes of both sexes were united in a single individual. The idea of hermaphroditism, which they had readily accepted, was at last proved correct, and exemplified among some of the inferior animals by which we are surrounded,—the earthworms and slugs for example.

These discoveries, extended at a later period by Adanson's beautiful researches upon mollusks,* gave a new interest to the very difficult problem—Can any animal be a male *and* female parent, in the entire acceptation of the word, without having intercourse with another individual?

A great many naturalists, led by reason only, replied in the affirmative; but the direct observation of animals placed apparently under the most favourable

* "Histoire Naturelle du Sénégal," 1759.

anatomical conditions, was in opposition to this conclusion. It was known that in the earthworm and the slug the intercourse of two individuals was as necessary to the ends of procreation as in mammalia and birds. Réaumur also, who was then universally recognized as arbiter in all matters relating to Natural History, was about to decide in the negative, when he was suddenly left in a state of doubt by some facts which he had observed when studying the plant-bugs (Aphides).

Most of our readers are acquainted with these insects in the larval stage. They are the creatures which appear in thousands upon the branches of fruit-trees, and the stems of flowers and of peas.* They are

* The plant-bugs (Aphides) are insects belonging to the order Hemiptera, that is to say to the group which includes the Cicadidæ, Cimicidæ (bugs), &c. They form a very extensive genus, whose species are even yet far from being all known. These insects are genuine parasites, living upon vegetables, and in these temperate climates there is hardly a single plant but what supports its own species of aphis either upon its stems or its leaves, or about its roots. Many species of Aphis may be classed among the noxious insects. Réaumur discovered that the punctures made by them, when in sufficient quantity, not only exhausted the plants, but gave rise to nodular swellings, and to alteration of the tissues. The laniger plant-bug (*Lachnus laniger*), which attacks apple-trees especially, has on many occasions destroyed the plantations of Normandy. This species, which is one of the disastrous results of commercial intercommunication with other countries, was found in England, according to M. Tougard, in 1787. In 1812, it had reached the French departments of Côtes-du-Nord, Manche, and Calvados. In 1818, it made its appearance in Paris in the garden of the "École de Pharmacie;" it was seen in the departments of the Seine-Inférieure, the Somme, and the Aisne in 1822. Finally, it was discovered in Belgium in 1827. This formidable little insect has for some years held its sway in the southern departments, no means of destroying it having been discovered.

almost invariably motionless, and having their long proboscis deeply buried in the epidermis of the plant, they appear capable of only one movement,—that of raising from time to time the great round abdomen which is terminated by two small tubes in the form of moveable horns. Each time they move, a drop of sugary liquid escapes from these openings, and in the neighbourhood may usually be seen a few ants, ready to suck up the honeyed secretion, which according to Hubert,—the distinguished observer of these insects,—is probably their sole nourishment. These larvæ, when completely developed, become pretty insects, with four transparent wings almost twice as long and as wide as the entire body, and which are supported by a few thin nervures. So far there is very little extraordinary in the history of these hemiptera.

The larvæ alone were at first examined by Leuwenhoek, La Hire, and Réaumur. The latter, whose attention was absorbed by other researches, afterwards engaged Ch. Bonnet to investigate the subject, and the Swiss naturalist fully justified the confidence reposed in him by his illustrious master.

It was already known that the plant-bugs produced two generations, and it was suspected that each individual possessed the two sexual attributes. To ascertain the truth of this suspicion, Bonnet isolated one of these insects almost immediately after its birth, and reared it in captivity, taking the greatest precautions to prevent any intercourse with other individuals. This nurseling was treated by our observer with an amount of care which he has naïvely described in his work.* He watched it with a lens, from

* "Traité d'Insectologie," 1745.

morning till night, noting its every action and gesture, anxiously following its slightest movement, trembling almost at the changes which seemed to result from excessive health, shuddering at the notion of an attack which might prove fatal; but all these anxieties were quickly forgotten when he saw the little being four times change its skin, and attain its normal specific characters. Bonnet was enabled to prove that a complete removal from all other members of its species did not affect its fecundity. On the eleventh day his virgin aphis—for so he thought fit to term it—gave birth to a young one, which was perfectly healthy; and a second soon followed the first. The same occurred during the succeeding days. Every twenty-four hours the family was increased by an addition of from three or four to ten new members. At the end of twenty-one days the mother, whose virginity was unquestionable, had given birth to *ninety-five* new beings.

This experiment, which was first made upon the aphis of the spindle-tree, and was repeated afterwards on a great many species by different observers, was decisive. The *lucina sine coïtu* of the ancients was proved incontestably in the plant-bugs; but these insects reserved for Bonnet a discovery which was quite unexpected.

Stimulated by some remarks of a rival, of whom we shall soon have more to say, Bonnet commenced a new series of experiments to ascertain how far the reproductive powers of the mother would extend to the offspring and grand-offspring. The aphis of the elder-tree was isolated immediately after its birth, and, as in the case of the former one, produced a

number of young. One of these latter was then imprisoned, and it gave birth to a third generation. A young specimen of this generation was placed under exactly similar conditions, and gave rise to a fourth, and so on. Five generations of virgin aphides were produced in Bonnet's first experiment. He afterwards obtained as many as ten, in the case of the spindle-tree aphis; and this number has been exceeded.*

It seemed fair to conclude from all these experiments, that, among aphides, a single isolated individual is capable of perpetuating the species. But in Zoology, of all sciences, it is especially necessary to guard against hasty generalizations, and Bonnet very soon proved the truth of this statement.

About the end of the year which afforded him so many interesting results, and whilst he was investigating the aphides of the oak, Bonnet distinctly observed the males and females of this species; he witnessed performances exactly like those which take place among other insects; in fact, he saw the female aphides produce genuine ova, instead of the virgin larvæ which he had before observed. This species exhibited, moreover, the phenomena of solitary viviparous reproduction which he had seen before in other instances.

* These results show with what rapidity reproduction is effected among the plant-bugs. Supposing a single aphis to produce only fifty young ones—which is certainly below the average—it follows that one of these insects beginning to breed in spring would give rise in the course of a summer to no less than 4,000,000,000,000,000 of larvæ, which would cover a space of at least forty thousand square metres. The entire surface of the globe would be covered with aphides, were it not for the number and voracity of the animals which prey upon them.

Bonnet was enabled by a new series of observations, to associate and explain in the most satisfactory manner these apparently contradictory facts. He discovered that the aphides produce larvæ without sexual intercourse, during the summer months only, and that when the external temperature diminishes, these insects return to the ordinary process, and propagate by ova, which can only be produced through the intercommunication of the two sexes. These ova remain attached to the branches of trees during the winter, occupying the position which the colony—now destroyed by cold—formerly held. They are hatched in spring, and *viviparous* individuals *alone* are produced; but in the autumn males and females again appear, and with them the oviparous reproduction presents itself.*

The facts to which we have just called attention

* De Geer, who may be called the Swedish Réaumur, Lyonnet, the distinguished anatomist of the willow caterpillar, and several others, have confirmed this conclusion. One of them, Kyber, has demonstrated incontestably the influence of temperature upon these phenomena. He placed a twig of carnation covered with aphides, in a chamber, which was maintained at a constant temperature all the year round, and observed, that these insects propagated viviparously, and in this manner only, for four successive years.—(*Germar's Magazin der Entomologie*, 1815.) These strange phenomena have often puzzled naturalists, and among those whose attention they have engaged, we may mention: Duveau ("*Nouvelles Recherches sur les Pucerons*,"—Mémoires du Muséum, 1825); Morren ("Mémoire sur l'Emigration du Puceron du Pêcher et sur les Caractères et l'Anatomie de cette Espèce,"—Annales des Sciences naturelles, 1836); Siebold "Ueber die inneren Geschlecteswerkzeuge der viviparen und oviparen Blattläuse;" Froriep's "Neue Notizen," 1839; and V. Carus "Zur nahern Kenntniss des Generationwechsels," 1849.

were of too peculiar a nature, and too inconsistent with accepted views, not to have given rise to many hypotheses. If the aphides always produced their larvæ without sexual intercourse, then the theory of Androgynism would have afforded a sufficient explanation. It would have been easy to suppose the existence in these insects of a double reproductive organ (male and female) in each individual, which could originate new beings in the same manner as those of opposite sexes when distinct. But the alternation of these two modes of generation set this hypothesis aside.

Bonnet, who was an acknowledged supporter of the "pre-existing germ" doctrine, saw no difficulty in the viviparous production of larvæ without previous sexual connection. According to him, the larvæ were only germs which were well supplied with nutritious materials by the mother during the summer months, and which on that account were fully developed *before* leaving the parent. The *ova*, on the other hand, were germs which had been imperfectly nourished. The action of the male aphis was regarded as an additional means of supplying the ova with nutriment, in order that they might survive the winter and be hatched in spring.

Réaumur, who was more observant and less metaphysical than his disciple, was much more puzzled. He put forward several hypotheses without committing himself seriously to any of them. One of these was at all events ingenious. It tended to show that oviparous reproduction and its results were in some measure dependent on the arrival of the insect at a state of puberty. He supposed that the adult condition was not reached after the individual had lived

for a certain period, but that it could only be attained in proportion to the number of generations which had preceded the birth of the insect. This explanation did not hold its ground any more than those which had preceded it, and took no position in science, for it deserved none, seeing that it never touched on the real difficulty—the fecundity of the virgin aphis.

According to another author, the aphides invariably produce ova in the same manner as other insects, but the fecundation instead of affecting merely one generation, extends its influence to several successive ones; hence, a second impregnation is unnecessary till the entire of this transmitted influence has been exhausted. According to this hypothesis, the ova are developed in a fecundated condition, and are hatched in the mother's uterus, just as they are among the ovo-vivipara.* The phenomena observed in the aphides, when seen from this point of view, resembled those already known, and although somewhat exceptional, still they came almost within the limits of the general law. The very vagueness of this explanation was a recommendation to some zoologists, and caused it to be accepted generally; and until of late years it remained almost unquestioned.

Shortly after Bonnet made his curious discoveries, naturalists observed another series of phenomena far

* Animals are termed ovoviviparous, which produce ova like true ovipara but which retain them in the uterus until the period of hatching; the young being then expelled without however possessing any of those connections with the mother's organism which are seen among mammalia. There are instances of ovo-viviparity among reptiles (the viper), fishes (the blenny), mollusca, and annulosa.

less reconcilable to what were then regarded as the fundamental laws of science.

Until about the first third of the last century, the real nature of various bodies was unknown or misunderstood. One distinguished botanist, Tournefort, relying upon some observations which he had made in the cave of Antiparos, and as Fontenelle said, "*transformant tout en ce qu'il aimait le mieux*," believed in the vegetative growth of stones. Notwithstanding the very clear views which had been enounced more than a century before by an Italian named Imperato,* he and most naturalists with him believed that calcareous polyparies were nothing more than vegetative stones. Others, seeing a sort of relation between them and the horny polyparies, regarded both as plants. Indeed this opinion seemed demonstrated by Marsigli,† who described the animals of the corals and other allied forms, as being nothing more nor less than flowers. But whilst the Italian naturalist published a discovery which was probably due to the fishermen of Marseilles, a French naval physician observed similar appearances, and grasped more fully their importance and signification. Peysonnel declared (in a memoir addressed to the French Academy in 1727) that he had ascertained by repeated observations, that the so-called flowers of corals, madrepores, and lithophytes, were genuine animals like the actineæ, zoophytes known since the time of Aristotle as sea-nettles (Acalephæ).

There was a very powerful reason for the rejection

* "Historia naturalis," 1599.

† "Histoire physique de la Mer," 1725.

of Peysonnel's views. Réaumur, who was imbued with the existing opinions, announced the discovery to the Academy, but opposed it also, and gave the entire weight of his authority in support of a slightly modified version of Marsigli's doctrine. Being desirous, however, of sparing one whom he esteemed, the annoyance of such a sudden rejection, he refrained from mentioning Peysonnel's name.* The latter, certain of the accuracy of his observations, appealed to men of science in other countries, and published his researches in the "Philosophical Transactions"† of the Royal Society of London. Some years afterwards, Trembley, the fellow-countryman of Bonnet, re-discovered, in Holland, the hydra,—which had already been met by Leuwenhoek—examined this fresh-water polyp, and announced those discoveries which have immortalized him; Bernard de Jussieu and Guettard having been sent by the Academy to investigate the sea-shore animals, and having carefully studied this portion of the marine world, confirmed all Peysonnel's statements. Réaumur bowed to the evidence of these witnesses, and with a greatness of mind and generosity which cannot be too highly praised, he himself proclaimed his past error, and the immense importance of the discovery made by him whom he had opposed, thirteen years before.‡

One of those accidents which often happen for those

* This essay of Réaumur's was reprinted in the "Mémoires de l'Académie des Sciences," 1727.

† "Philosophical Transactions," vol. xlvii. This work was partly reprinted in London, in 1756, when the accuracy of his views had been demonstrated.

‡ "Mémoires pour servir à l'Histoire des Insectes," preface to the sixth volume, 1742.

who seek them, placed Trembley upon a new path of study. He placed in a glass vessel a quantity of ditch water, whose surface was covered with those little isolated plants which consist of two spreading green leaves and some fine rootlets, and which are commonly known as "duck-weed." After a while he perceived a number of small bodies of a beautiful green hue attached to the transparent walls of the bowl, and which gradually changed their form and proportions, sometimes remaining perfectly motionless, and at others travelling slowly along the glass. When completely elongated, their bodies were like hollow cylinders, five or six lines long, whose free extremity exhibited a central orifice, and was surrounded by a variable number of retractile tentacles, moveable in every direction. On touching them, these tentacles were rapidly drawn in, seeming to disappear altogether, and the cylinder was reduced to the form of a conical projection, hardly one line in length.

Trembley was for a long while ignorant of the real nature of these curious bodies. Were they animals? or were they plants endowed with the power of sensation? The form and colour were those of a plant; but on the other hand these bodies moved along sometimes indeed very slowly, but at others by making a series of bounds, by no means unlike those of a mountebank. To solve this problem, he cut one of these enigmatical beings in two, and in forty-eight hours after, each half had become a perfect organism like the original. When it was divided into twenty, thirty, and even fifty portions, there were as many perfect individuals produced. At the same time

Trembley discovered upon these living cylinders a number of small elevations, which gradually increased in length, developed tentacles at their free extremities, and ended by becoming detached, when they were found to resemble in every particular the body from which they had sprung.

Here, Trembley observed two important phenomena which till then had been regarded as belonging to plants exclusively—multiplication by *fissuration* and by *buds*. He also saw these pseudo-plants feeding like beasts of prey, seizing with their tentacles the aquatic insects as they swam along, swallowing them —sometimes as large as themselves—wholesale, digesting them, and rejecting the effete matters by the same orifice through which the food was admitted. These facts seemed to him to decide the question. The beings which he had been studying so long were actually and certainly animals. Réaumur, who was consulted as to this conclusion, adopted it as soon as he had seen the creatures themselves, and thereupon gave them the name of polyps, which has since been applied to the entire class. With the assistance of Bernard de Jussieu he found a species akin to that of Holland in the outskirts of Paris, and other animals also which he thought, but incorrectly, were related to it.*

Trembley's discoveries so fully confirming those of Peysonnel, produced quite a sensation; in fact, to use the language of the period, "court and town" were

* The "polypes à panache" (Polyzoa), of Réaumur and his contemporaries, have only a faint external resemblance to the true polyps. The latter belong to the sub-kingdom Radiata; the former have been properly ranked among mollusca.

full of it. The first polyps sent from Holland were solemnly presented to the Academy by Réaumur himself, who at the same time pointed out other animals capable of exhibiting similar phenomena. The subject was then taken up on every side. On the coasts of Bretagne and Anjou, there was almost a species of rivalry exhibited by Bernard de Jussieu and Guettard in the manner in which they cut up the Actiniæ and Asteriadæ. The reproduction of lost parts was shown to take place in both these groups. They not only determined the animal character of a great number of polyps, but they went even farther in grouping among the latter several calcareous plants which have been very gradually restored to their proper places. Then, again, Réaumur and his colleagues investigated the fresh waters; and the Bryozoa of our ponds, the Planariæ and Naïdes of our streams, and even the earthworms, exhibited in various degrees an insensibility to mutilation, the prominent result of which was their individual multiplication. A grand physiological truth was deduced from all these experiments; viz., that certain animals may, like plants, be reproduced both by slips (fissuration) and by buds (gemmation).

It was evident that in these instances there could be no question of ovo-viviparism; hence it became necessary to go in search of some new explanation, and the metaphysicians, whether naturalists or not, took part in the inquiry. At this period the doctrine of "*pre-existing germs*" reigned supreme. How then were the newly discovered facts to be reconciled with this theory? Bonnet, in his endeavour to solve the problem, devoted a considerable deal of thought to the subject, and concluded by developing an en-

tirely new speculation—a peculiar theory termed that of "*panspermy*," which supposed the constant existence and universal diffusion of germs that were always ready to be developed. On the other side, Descartes' followers took the matter up, and asked those who believed in the existence of a soul among the lower animals, what became of the soul of a polyp which had been divided into fifty portions, each one of which assumed the character of an individual? Was the soul divided into as many portions as the body, or did it remain in some favoured segment? Did the fiftieth part of the soul, in the first instance, become eventually developed? How, in the second case, could the portions first deprived of a soul perform their functions as well as those in which it was left intact? Or, were there indeed not only *bodily* germs but *spiritual* ones also? These questions, as well as many others, were discussed at the time with considerable spirit, but the excitement gradually calmed down. Unsolved problems were laid aside; and, thanks to the ventilation, and even to the number of the facts, it was considered as easy to conceive of an animal reproducing itself after the manner of plants, as to suppose that an insect could be oviparous and viviparous alternately, and that a single act of fecundation influenced not only the generation immediately succeeding it, but future generations also.

For more than three-quarters of a century, naturalists continued to explore the paths which had been thrown open to them by the discoveries of Bonnet, Peysonnel, and Trembley. Facts were rapidly accumulated, but no *new* phenomena were observed. There are among the works of this period some

which deserve attention, and whose importance was not appreciated till they were examined from a point of view which was for a great length of time unrecognized.

As the result of the discoveries we have alluded to, several organisms were ranked among the relatives of the hydra, which were really in no way akin to it. Such were the corallines, which are undoubted vegetable structures, and the *Flustræ*, *Escharæ*, and *Botrylli*, which belong to the *compound* or *aggregated mollusks*. Their true nature was demonstrated in 1816 by Savigny, the companion of Geoffroy and Cuvier, he who suffered thirty years' martyrdom for his endeavours to advance science. The multiplication of individuals occurs in all these species in the same manner as in the polyp with which they were confounded.* The several modes of reproduction discovered by Réaumur's contemporaries were thus presented by different animals, among some of which, the various individuals were connected together organically; thus converting them into animal colonies capable of growth and of extension. Reproduction by fission and gemmation only explained the multiplication of the individuals of the colony in *one* locality, but left unsolved the question of the distribution of the colonies themselves.

* "Mémoires sur les Animaux sans vertèbres." On Savigny's return from his Egyptian expedition, and whilst in the pursuit of his studies, he was attacked by a very extraordinary and calamitous disease of the eyes, which deprived him of his vision for thirty years. Cuvier remarked, in a report to the Institute upon one of the first memoirs of this naturalist, "Savigny does not merely discover, he reveals;" so unexpected but withal so clearly demonstrated were the results enunciated.

This problem remained unexplained till about the first third of the present century.

It is quite true that Bernard de Jussieu had discovered the hydra's eggs; that Cavolini, then residing at the sea-side, had observed the eggs, or the *whirling germs*, as he termed them, of the polyps, and had seen them attach themselves to some solid body and give rise to a new polypidom;* and that many other facts had been recorded. Nevertheless, the problem was left in nearly as much obscurity as ever, until Messrs. Audouin and Milne Edwards declared that the *compound ascidians* deposited true ova, from which sprung larvæ, at first restlessly active, but which eventually became fixed, and developed a new colony.† This important discovery, which was at first denied, but afterwards confirmed by several naturalists, was the start-point of a series of most valuable researches made by Milne Edwards; and we shall now proceed to give a brief *résumé* of them.‡

The ascidians are marine mollusks without shells, and may be divided into three distinct groups. In some the individuals are free and isolated, and are hence called *simple ascidians;* in the second division the members are loosely connected by trailing root-like prolongations, and are termed *social ascidians;* whilst the individuals of the third section are fused as

* "Memorie per servire alla Storia dei Polypi marini," 1789.

† "Observations sur les Ascidies composées des côtes de la Manche en 1834 et 1839." Since that date Van Beneden has observed the same forms of reproduction among the *simple* ascidians. —"Recherches sur l'Embryogénie, l'Anatomie, et la Physiologie Ascidies simples," 1846.

‡ "Résumé des Recherches sur les Animaux sans vertèbres, faites aux îles Chausey," 1828.

it were into a common mass, and, having the closest possible organic relation to each other, are therefore styled *compound ascidians*. The first appear as irregularly globular masses attached to sub-marine bodies; the second are usually found suspended from the roof of some rocky cavern, and have the appearance of beautiful crystal ornaments; the third are seen covering whole rocks, stones, and sea-weeds. The mass is usually of a gelatinous character, semi-transparent, and tinted with red, green, or brown; and upon the surface of each colony a number of irregular festoon-like markings may be observed, figures which are by no means unlike those traced by a mathematician's compass. Moreover, the organization of all ascidians is in the main identical. They have all a very simple nervous system, a very imperfect circulatory apparatus, a more or less contorted digestive canal, and in many of them, owing to the extreme transparency of the integument, the whole anatomy may be studied with the aid of a simple lens, without having any recourse to the dissecting-knife.

The egg of the compound ascidian is very rapidly developed, and exhibits the same phenomena as those described in the earlier chapters of this volume. It is entirely converted into a larva like that of Hermella and Teredo. This little creature is of an oval form, and is furnished with a long tail which gives it some resemblance to a tadpole. As yet there are no distinct internal organs, but in their place is found a central homogeneous yellow mass, from which they will be formed, and which is surrounded by the thick, colorless, and transparent envelope. A prolongation of this mass extends into the tail, and three others act

as suckers, by which the animal adheres to submerged bodies.

At first the young ascidian swims about very nimbly, but its energy is soon exhausted, and after a few hours it becomes permanently fixed. The prolongations of the yellow mass are drawn toward the centre of the body, the tail becomes atrophied and is detached, here and there may be seen traces of organization, the heart and digestive apparatus gradually appear, and at the end of the third day, all the organs have begun to perform their functions. Simultaneously with these changes the integument is thickened and enlarged. It is this which will form the common matrix for all the inhabitants of the future colony. Numbers of buds now appear upon the body of this solitary animal; these force their way through the matrix and reach the external surface in a certain definite order, constant for each species, and then, instead of a single isolated ascidian, there is a cluster of compound mollusks, each of which will produce eggs at the proper time.

We see then, that in the ascidians, as in the aphides, an animal which has sprung from an egg develops, without previous sexual intercourse, a number of new beings, and finally, coming under the ordinary law, deposits true ova.

CHAPTER XIV.

DISCOVERY OF ALTERNATE GENERATION (SALPÆ AND MEDUSÆ).

By combining the precise observations of Milne Edwards with those of his predecessors and followers, we are enabled to draw the following general conclusion:—The distribution of fixed animals is apparently always due to the development of eggs produced by the female, and which are hatched at a distance, giving rise, in most instances, to free and active larvæ. Here we observe both metamorphoses properly so called, and the recurrent form to which we referred elsewhere; * besides, multiplication by buds occurs in those individuals belonging to the *social* group.

This twofold method of propagation is evidently necessary, and might suffice to ensure the existence of polyps and other animals which live in colonies. But organic nature, which is not limited to a single or to the most simple path, had other surprises in store for naturalists. In 1819, a Germanized Frenchman—who must be admired by those who have read M. Ampère's essay† — recorded a discovery, which in novelty, and from the fact that it was unexpected, was in no way inferior to those which pre-

* *Vide* Chapter V.

† "Revue des deux Mondes," May 15, 1840.

ceded it. Chamisso detected the mode of reproduction of the biphoræ, and coined the expression "alternation of generations."

The Salpæ are marine mollusks of a very peculiar form, to give a general description of which is exceedingly difficult. However, we may describe them as being like an irregular cylinder of perfectly transparent crystal, in the centre of which a proportionally small mass of opaque, brilliantly coloured matter, called the *nucleus*, is suspended. This nucleus is composed of the principal viscera grouped together. The cylinder represents the mantle and shell of other mollusks, and is perforated at both extremities. The water which is required for respiration is introduced through one of these orifices, and by the contractions of the mantle is as quickly expelled from the other; this action taking place with rapidity, the animal is caused, as it were, to rebound; and thus by these respiratory contractions the biphora is propelled through the water.

For a long period the attention of travelling naturalists had been attracted by these animals, whose phosphorescence was distinctly marked even in the luminous waters of the intertropical ocean. They had been seen sometimes in the isolated condition, and at others in the form of long ribands composed of exactly similar individuals. There were, moreover, very considerable and well-marked differences between the chained and isolated Salpæ. The existence of these two conditions seemed a sufficient reason for the division of this singular group into two distinct sections; consequently, it was supposed by our celebrated traveller, Péron, that the Salpæ, which were

connected in the young stage, were afterwards isolated, and caused to assume other characters in obedience to the laws of development. He thus admitted the existence of *true* metamorphoses, for the distinction between the two forms—solitary and aggregated—extends not only to the external character, but also to the form and disposition of the viscera.

Chamisso discovered that this phenomenon is far more complex than was supposed.* He perceived that the Salpæ are both *androgynous* and viviparous, and that they preserve their infant characters all through life; but, strange to say, a solitary mother produces *only* individuals united into colonies, and *vice versâ*. Hence it follows, that a Salpa resembles neither its parents nor its offspring, but is exactly like its grandparent and grand-offspring. The external and internal characters of the alternate generations are, moreover, in every respect identical.

In this case, metamorphosis does not affect individuals merely, but operates on entire generations. The same result is produced as if the caterpillar, instead of undergoing its transformation, were to produce a fully-formed butterfly, which in its turn would bring forth caterpillars. It is a true *alternation of generations*, and this law holds good for all biphoræ.† Consequently, the species of these mollusks

* "De Animalibus quibusdam e classe Vermium linneana. Fasc. prim., de Salpis." 1819.

† The following passages from Chamisso's memoir will show that I have almost employed the very words of this naturalist, "Quâ repositâ (Salpâ bicorni), alternationem generationum legem esse, ut posuimus genericum, omnibus communem speciebus, observationibus innititur. . . . . Talis speciei metamorphosis generationibus in salpis duobus successivis perficitur, formâ per generationes (nequa-

cannot be determined by reference to the characters presented by one individual, even during its entire life; it will be necessary to examine the individuals of two *successive* generations, and to describe two forms instead of one.

Chamisso's discoveries seemed as incredible as the "Adventures of Peter Schlemihl." They were denied in the first instance; but then, as they were gradually confirmed by new observations, an effort was made to unravel their mysteries; this, however, could not be done satisfactorily so long as the facts remained isolated. Besides, even the then existing observations left a considerable gap in the history of biphoræ, which was only filled up at a much later period by the works of Krohn,* Huxley,† Leuckart,‡ and Vogt,§ to which we shall allude presently.

quam in prole seu individuo) mutatâ. Verum enimvero quâ lege proles salparum, ut animal ab ove, imago a larvâ inter se differunt, parum elucet."—(De Salpis.) "Es ist als gebaëre die Raupe den Schmetterling, und der Schmetterling hinwiederum die Raupe."—(Reise um die Erde.) Professor Huxley, who I believe was the *first* to do ample justice to Chamisso, has quoted, among others, the above passages.

* "Observations sur la Génération et le Développement des Biphores."—Annales des Sciences naturelles, 1846.

† "Observations upon the Anatomy and Physiology of Salpa and Pyrosoma."—Philosophical Transactions, 1851.

‡ "Zoologische Untersuchungen," zweites Heft, 1854.

§ "Recherches sur les Animaux inférieurs de la Méditerranée," second memoir, 1859. Although Vogt's work stands last in the order of publication, it is but fair to state that his observations date from the year 1847, and were carried on with great care from 1850 to 1852, when they were communicated to the assembly of Swiss naturalists. The very abundance of the materials collected by this distinguished and industrious zoologist retarded the publication of the memoir referred to.

Chamisso, less fortunate than Peysonnel, died, not only before his opinions had received recognition, but even without having himself understood the immense importance of his discoveries.

Chamisso's observations, at first certainly incomprehensible, and those, still more obscure, announced by Carus, in 1818, as the result of his researches on the *Helminthes, or intestinal worms,* marked an entirely new era in the history of development. By these pioneers a path was thrown open, along which we travel every successive day with more and more security, but in which it is also possible to lose the right track, and thus commit serious errors. The entire history of these explorations, made to determine the proper route, is pregnant with interest, but it would occupy far too much space, and is of too difficult a nature, for us to pursue it. We must, therefore, confine ourselves to setting down the landmarks, as it were, of the paths traced by those who first visited this "unknown land;"* and in doing so, we shall occasionally be obliged to invert the chronological order of the discoveries, in order to present the reader at first with the typical results. Under the latter category the works of Saars and Charles von Siebold, on the reproduction of Medusæ, occupy unquestionably the first rank.

We shall now detail certain facts which, though well known to all naturalists, are unfamiliar to most of our readers.

For almost half a century, the classes *Acalephæ* and *Polyps* have held a place among the other

* An expression employed by Siebold, to designate especially the history of the reproduction of the Helminthes.

divisions of the sub-kingdom Radiata, and the distinction between the two seemed a very justifiable one. Indeed, it had been shown, that differences exist between them of a more decided character than those which separate reptiles from birds; there is an entire dissimilarity both as to internal organization and external conformation.

All acalephs are free and floating, and most of them are solitary. The movements of polyps (which are confined to a few) are, on the contrary, of a creeping nature. Almost all these animals are permanently fixed, and the great majority of them live in colonies. Trembley's Hydra is a type of the latter, while the Medusæ belong to the former, and may be readily known by their peculiar *umbrella*, shaped like a bell or a mushroom,—in some instances colourless and transparent; in others, beautifully opaline, and having an appearance not unlike that of tinted enamel. This umbrella is at once the body and locomotive organ of the animal; the digestive cavities and circulating canals are buried in its substance, and by its rhythmic contractions the animal is propelled through the water. In the centre of the concave surface—in fact, in the same position as the stalk of the mushroom and the tongue of the bell—is placed the mouth, which is almost always surrounded by various appendages. The border of the umbrella is frequently furnished with cirrhi, which are occasionally both long and contractile, and serve as arms or fishing-lines, by which the prey is seized, destroyed, and carried to the animal's mouth.

The observations on the reproduction of Medusæ had been few and isolated when Saars and Siebold

published their beautiful researches. The former, who was a native of Bergen and a clergyman, devoted his leisure hours to the study of the rich marine fauna of the Norwegian coasts. In 1820 he described two polyps akin to Hydra as new species, giving them the names of *Scyphistoma* and *Strobila;* but he afterwards (1833) discovered that the second of these creatures was only a transformation of the first. In 1835 he stated that the strobila produces genuine acalephæ, by a process which till then had been unobserved.* On his side, Siebold, who was one of the first of German naturalists to perceive the import of marine creations, clearly distinguished the sexual organs of the Medusæ, watched the first transformations of the larvæ which proceeded from the ova, and saw them converted into true polyps. † Finally, Saars, in a memoir,‡ which was soon translated into every European language, co-ordinated and completed this history, which till then had been in but a fragmentary condition. We shall now give a short sketch of the results which have been arrived at.

The red Aurelia (*Medusa aurita*), which Ehrenberg's writings have made almost as celebrated, as those of Lyonnet the willow-moth,§ is a pretty creature, with

* "Beskrivelser og Jattagelser over nogle moerkelige eller nye i Havet ved den Bergenske kyst levende Dyr." A portion of this work was translated by M. Gervais in the "Annales d'Anatomie et de Physiologie" for 1838.

† "Beiträge zur Naturgeschichte der wirbellosen Thiere."

‡ "Mémoire sur le Développement de la Medusa aurita, et de la Cyanea capillata," in the "Annales des Sciences naturelles" for 1841.

§ The organization of medusæ had been considered very simple till this work appeared in 1839, in the Memoirs of the Berlin Academy. It was thought that the cavities and canals which

an almost hemispherical umbrella, of from ten to twelve centimetres wide, of a pale red colour, which is due to the vascular ramifications, and provided at its margin with numerous short reddish tentacles.

The Aurelia deposits ova, which are characterized by the presence of the three concentric spheres to which we alluded in the third chapter of this volume, and these eggs are converted into larvæ, which are at first not unlike those of Hermella and Teredo. Their oval body, which is apparently quite homogeneous, is covered with vibratile cilia, and presents a little depression anteriorly. For some time they swim about very actively, just like Infusoria, which they resemble so strongly, that any one confining his observations to this portion of their existence, would certainly be deceived as to their real character.

This first phase in the life of Medusæ extends over a period of about forty-eight hours. The movements then become more feeble, and the young larva seems exhausted, and attaches itself to some solid body, by means of the little depression already mentioned. The animal, which had hitherto been nomadic, henceforth is fixed and stationary, and a thick mucus, which

Duméril discovered, about the end of the last century, were mere excavations in a homogeneous matter, devoid of the characters of a tissue. Oken and his disciples founded part of their doctrines on this statement, which they accepted without examining. Ehrenberg demonstrated that there are tissues, organs, and even complex systems present in the Aurelia. He did in our days, for this group, what Lyonnet did in his for the insect class, and by depriving the "Philosophie de la Nature" of one of its chief foundations, he conferred a signal benefit on Natural Science. Besides, other naturalists, and especially Agassiz, Edwards, Huxley, and Will, have confirmed the general results of the Berlin savant's researches, and I myself have on many occasions perceived their accuracy.

it secretes, spreads out in the form of a wide disk, and connects it firmly to its future home.*

The young Aurelia changes its form and mode of life simultaneously. It becomes elongated rapidly; its foot-stalk is narrowed, and its free extremity assumes a club-like form. An opening soon presents itself in the centre of this extremity, and exhibits an internal cavity; four small projections or papillæ appear upon its border, and in process of growth are converted into as many tentacles; and gradually others appear also, and are completed in their turn. In fact, the infusorian is transformed into a polyp; and it is this which Saars first described under the name of Scyphistoma.

In its polypoid condition the Medusa exhibits all the characters and properties of the real polyps. It is propagated both by buds and *stolons*.† Occasionally the buds produced upon a portion of the body soon reproduce individuals like the parent; in other instances they give rise to a slender stem, which trails along the ground for a certain distance and develops little tubercles, which in their turn will become scyphistomæ, all resembling as many short, wide-mouthed trumpets, whose borders are furnished with from twenty to thirty slender moveable filaments. Each of

* I have merely given Saars's opinion; but it is more probable that this quasi-mucus is a true sarcodic expansion, analogous to those observed in the development of many other inferior animals, even of sponges.

† Stolons or shoots are terms applied to those slender branches of a plant, which starting from the bottom of the stem, grow out laterally to some distance and then taking root produce a new individual. The strawberry plant affords a very familiar instance of this mode of multiplication.

the beings thus produced performs the same functions as its parent, and gives rise to other generations; thus rapidly increasing the size of the whole colony. The process is just that which we see in a strawberry plant, throwing out its slender *runners* in every direction, which, becoming contiguous, eventually produce an entire border of new plants.

The Medusa lives for some time in this condition, but, in course of time, one of the trumpet-shaped bodies becomes three or four times as long as its fellows, and assumes a cylindrical form. A single circular depression is then seen, immediately below the crown of tentacles; this is quickly followed by others, till at length the entire stem is marked at intervals almost to the very foot-disk, which, however, remains intact. The body of the polyp consists now of a series of rings, from ten to fourteen in number.

These rings are smooth at first, but after a while their inferior borders are festooned; these festoons then become more marked; and, finally, the angles are drawn out, and they are converted into eight little leash-like organs, bifurcated at their extremities. At the same time, the intermediate grooves have gone on deepening, till they have extended almost to the central axis of the polyp. The latter at this period resembles a pile of little plates, whose edges are deeply cut and very flat, and which are attached to each other by their centres. The scyphistoma has, so to speak, cut itself up into slices. It is to this stage in the life of the Medusa, that Saars gave the name of strobila, and we see that the Norwegian naturalist's mistake was a very pardonable one.

Although still imperfect, yet when they reach this condition of development, the divisions of the strobila show unequivocal signs of individualization. Each of them moves its own fringed border separately, and if a single one be touched, it alone will contract. In order that all these divisions of the former animal may become as many distinct individuals, it is necessary that they separate; and this they speedily do. The topmost one, that which bears the tentacles of the scyphistoma, is first detached, and those which succeed it are similarly removed, and swim away through the water after the manner of acalephs. They are now *medusoids*, but not yet aurelias, and Saars very fairly compared them to the species of another genus — the eight-rayed ephyra (*Ephyra octoradiata*).

Neither the form nor the organization is what it will be eventually, but the larvæ are soon fully developed. At first flat, as above described, they now become more and more convex on one side and concave on the other; the gastro-vascular canals make their appearance; the mouth is opened and surrounded by its tentacles; the marginal cirrhi present themselves, at first few in number, but afterward more numerous, and the reproductive organs, male and female, are formed in separate individuals, and soon commence the performance of their functions. Finally, instead of a solitary infusorian, or of a more or less branched scyphistoma, or of a strobila more or less segmented, or even of a swarm of *Ephyras*, we perceive numbers of red aurelias, exactly like that which laid the primitive ovum, but was unable to reproduce itself directly.

What would our readers think were we to express ourselves thus :—A butterfly deposits an egg, from which springs an earthworm that is soon converted into a caterpillar; from this caterpillar a series of buds are produced which become so many individuals like the first one; then each of these, although preserving the caterpillar head, assumes the body of the chrysalis; this body is constricted at intervals, and gradually becomes converted into a cluster of butterflies, piled up one upon the other; the caterpillar head then falls off, and the butterflies fly away one by one. At first they resemble moths; but by degrees they assume their true characters, and become beautiful diurnal Lepidoptera. Who would put any trust in a history which described a series of transformations as fantastic as those seen in a dream? Yet change a few of the expressions, employ the terms Acalephæ and Medusæ for those of insects and butterflies, and that which but a moment before had been mere fiction becomes simple truth.

CHAPTER XV.

NEW EXPLANATION OF FACTS LONG KNOWN.

It is necessary, before proceeding further, to designate the different phases of the successive multiplication we have been describing, by general terms, analogous to those of *larva*, *nymph*, and *perfect insect*, employed in the description of true metamorphoses. These principal phases are three in number. In the first instance, the egg gave rise to a simple being, an individual having neutral characters; that is to say, being neither male nor female; at a later period we observed a compound being, quite as neutral as the first, and each part of which was capable of carrying on an independent existence; finally, we saw these parts detached, and assuming the organs characteristic of the sexes. M. van Beneden, a Belgian naturalist, to whom we shall have to allude frequently, was the first to distinguish these three stages, and to apply separate names to them.* We shall gladly adopt his nomenclature.

Thus, we shall apply the term *scolex* to the animalcule which springs from the egg of the Medusa, or of any other species which is reproduced by analogous processes. Giving a more extended signification to the word *strobila* than that employed by

* "Recherches sur les Vers cestoïdes," 1850. "La Génération alternante et la Digenèse," 1854.

Saars, we shall designate by it all the compound beings which proceed from the scolex, and are destined to give rise to *isolated* individuals. Finally, borrowing Dujardin's expression, *proglottis*, which has been used by him in almost a similar sense, we shall apply it to the individual which proceeds from the *strobila*, and which, acquiring true reproductive organs, thus completes the circle.

We saw that from the Aurelia there was produced a scolex, which at first exactly resembled an infusorian, and afterwards assumed the polyp form; and that whilst in this condition it gave rise by gemmation to other polyps like itself. Hence, we find that there are several generations intercalated as it were between the primitive scolex and the strobilæ, which are produced by it; and, moreover, that these generations are not always similar. It sometimes happens that an individual which results from gemmation differs in many respects from its parent, or is even quite unlike it; just as might occur if a hairy caterpillar were budded from a smooth-skinned one. In this case, the first form is termed *protoscolex*,* the second *deutoscolex*,† and so on; Greek compounds being employed to designate the numerical order of the generation.‡

* Signifying *first* scolex.

† Signifying *second* scolex.

‡ Van Beneden, retaining the term *scolex* for the generation which produces the *strobila*, applies in certain cases the term *proscolex* to the race which precedes it. Hence there occasionally arises some slight confusion in the description of the phenomena. The simple rule which I suggest the adoption of, is merely a slight modification of the Belgian naturalist's views, and does away with the difficulty. M. Moulinié, in his splendid work on the *Endo-*

We may regard the reproduction of the Aurelia as typical of the group, although in regard to the number of the phenomena which it exhibits, it holds a median rank. There are far more complex and far more simple forms, but characters of plus or minus do not alter the real nature of the process of development.

Without inquiring into their precise signification, we may now indicate two important facts which bear upon those which precede them: firstly, each egg of the Medusa, instead of producing a single fertile animal, as is the case with that of the butterfly, gives rise to several individuals; and secondly, this production takes place *mediately;* for between every two generations of Aurelia many races of dissimilar beings are produced by gemmation.

To speak in a more general manner, we have here the production of *several generations,* through the medium of a *single germ.* This is, to my mind, the fundamental fact which rules all the secondary phenomena. It is this which I have endeavoured to convey in the term *geneagenesis,* which is applicable to all forms of reproduction that possess this essential character.

If with the foregoing history of the Aurelia we

parasitic Trematodes, rejects Van Beneden's nomenclature, and employs the words *embryo, nurse,* and *larva.* In this particular he agrees with the editor of the "Bibliothèque de Genève," who deprecates the change I have made in Steenstrup's nomenclature. We shall see further on, that as this nomenclature conveyed ideas which I considered inexact, and was out of keeping with the view I took of the entire phenomenon, it was necessary to alter it. Moreover, in adopting the expressions proposed by Van Beneden, I think I have once more shown how little anxious I am to introduce new terms into science.

associate those of the Hydra, the plant-bugs, and the biphoræ, and if we add the results of recent discoveries to those of older ones, we shall see that the phenomena of multiplication, which at first seemed exceedingly unlike each other, assume a sort of relationship, and form a somewhat natural group. This relationship was first made known by a Danish naturalist in a work which has been justly celebrated. By the publication of his treatise on "The Alternation of Generations,"* Steenstrup did good service for natural science; and although we do not share all his opinions, and even occasionally take quite an opposite view to those he has put forward, nevertheless we accord him full praise for all that is valuable in his researches.

We have already seen that Bernard de Jussieu was the first who discovered the Hydra's eggs. His successors, looking on this form of reproduction as useless to an animal which was propagated both by buds and by fission, regarded these ova as pimples which resulted from some disease; in fact held that the Hydra possessed no organ comparable with an ovary. These germs were secreted, so to speak, by the very walls of the body. Upon some portion of the body, and usually when buds have appeared, the skin is pushed out in the form of a cupel: in this spot the elements of the egg are gradually accumulated, and become surrounded by a sort of shell or covering furnished with bifid spines. The skin next bursts, and the ovum thus expelled attaches itself to the nearest body.

* "Ueber den Generationswechsel, oder Fortpflanzung und Entwickelung durch abwechselende Generationen," 1842. This work, to which we shall allude in the next chapter, was translated into English for the Ray Society by Mr. George Busk, F.R.S.

This mode of reproduction was first pointed out by Ehrenberg, the distinguished Berlin micrographer,* who afterwards discovered the zoosperms also of these animals. The Hydra, then, is hermaphrodite, and propagates both by ova and buds. But—and this is a fact of the utmost importance—the buds are always produced first, and the Hydra perishes as soon as it has produced ova. Thus, there springs from the Hydra's egg a simple individual—a *scolex*—capable of producing many others like itself, and which can also push out buds, but which ends as the parent does, by assuming the sexual attributes.

It is the same as if a butterfly's egg gave rise to an animal having all the *external* characters of the perfect insect, but devoid of reproductive organs, having the power of producing by gemmation other beings resembling itself, which, like it, would be capable of acquiring at a later period the male and female generative bodies.

Here we observe geneagenesis in its simplest form, deprived of all accessory circumstances, and of all the complications which result from change of form. The several generations of scolex are exactly similar, and each scolex is directly transformed into a *proglottis*, the *strobila* stage being entirely absent. The very simplicity of the process shows what is really its most fundamental part — viz., the production of several generations from a single germ.

The compound ascidians show us something additional.

In these the ovum develops a scolex, which becomes fixed, acquires well-marked reproductive organs, and

* "Die fossilen Infusorien," 1837.

gives rise by gemmation to a series of new and equally perfect individuals. In this instance the scolex is directly converted into the proglottis, which in its turn produces on all its sides an entirely new generation of individuals which resemble itself. There are, however, well-marked distinctions between these two phases of development.

Employing the same comparison adopted before, we should say in this case, that the butterfly's egg produced, first, a caterpillar, which reached the final condition; then, from the butterfly which was thus formed, others like the first were originated by budding, and the former was neither the father nor the mother of the latter, but simply the *parent*.

A somewhat more complex state of things takes place among the aphides.

The ovum which is deposited in autumn gives rise to a scolex having nymphal characters; and this nymph produces no eggs during the summer, but develops, instead, a number of genuine buds, which are matured and organized in the interior of the body, and not upon the external surface, as in the Hydra or Aurelia. As soon, however, as the temperature of the air becomes lower, the generative organs appear in separate individuals, and we then find males and females, or in other words true *proglottides*.*

* According to M. Heiden's published observations, an aphis after having produced, agamically, and during the whole summer, individuals like itself, can in the end of the season assume the sexual characters. In other words, a scolex may be transformed into a proglottis. The conclusions drawn from this fact regarded as entirely new, are exaggerated. This transformation does not at all alter the character of the phenomenon, especially when it is viewed from our stand-point. Leydig, in a very valuable essay in

This is, as it were, the history of a butterfly's egg, from which sprung a chrysalis capable of producing, by internal gemmation, first several generations of beings like itself, and then a certain number of butterflies. Here, then, are several generations of scolex; the strobila stage, as in the preceding cases, is wanting, and the proglottis is sometimes, even during its whole lifetime, like the scolex,* but at others differs from it in certain particulars already referred to.

This analogy between the external forms of the scolex and proglottis in the same species, renders it occasionally difficult to distinguish between the various phases of geneagenesis, and, as it were, masks the phenomenon. The process is more clearly seen among the biphoræ, where the physiological laws are in some measure indicated by the existence of perceptible characters.

This subject has been investigated by many natural-

the "Zeitschrift für wissenschaftliche Zoologie," 1850, on the earlier phenomena of development, was led to confound, so to speak, reproduction by ova with reproduction by fully-formed individuals. His view was opposed more or less clearly by Siebold, Owen, V. Carus, and Dr. Burnet, and in a more direct manner by Lubbock "On the Double Method of Reproduction in Daphnia"—Philosophical Transactions, 1857,—and Leuckart, "Zur Kenntniss des Generationwechsels und der Parthenogenesis bei den Insecten;" Moleschott's "Untersuchungen," 1858. Professor Huxley's admirable memoir "On the Agamic Reproduction and Morphology of Aphis"—Transactions of the Linnean Society, 1858,—in which he has not only summed up, but completed all the preceding researches, leaves this subject settled beyond doubt. We shall discuss all these questions further on.

* Bonnet has observed wingless individuals which performed the same functions as those with wings, and gave unequivocal proofs of sexuality.

ists since Chamisso's time, and among others by Eschricht of Copenhagen, who has given us a remarkable anatomical work, in which the very important fact is established, that the chained salpæ are united in colonies from the earliest period of their embryonic life.* Unfortunately, Eschricht's observations were confined to specimens preserved in spirit, and the credit of clearing up this history, which was for a long while considered fabulous, is due to two naturalists, the one an Englishman, the other a German. Thanks to the researches of Krohn† and Huxley,‡ we can now assert that among the biphoræ there is an alternation not only of form and of mode of life, but also of mode of reproduction. As the result of their united observations, it may be stated that the compound or aggregated biphoræ are hermaphrodite, and deposit eggs only, from which spring isolated biphoræ. These latter are neuters, and produce, by internal gemmation *only*, a series of aggregated biphoræ. Here we have, strictly speaking, no strobila, and there is but a single generation of scolices which produce directly a series of proglottides that remain united for the rest of their existence.§

* "Anatomisk-Physiologiske Undersoegelser over Salperne," 1841. I am acquainted with this work only through various extracts from it, given by other writers.

† "Mémoire sur la Génération et le Développement des Biphores.' —Annales des Sciences naturelles, 1846.

‡ "Observations upon the Anatomy and Physiology of Salpa and Pyrosoma."—Philosophical Transactions, 1851.

§ It was shown by Eschricht, that the *chain salpæ* are developed upon a sort of stolon situate in the interior of the isolated forms. This might fairly be regarded as a kind of strobila produced by internal gemmation, and concealed within the scolex.

Among the biphoræ, then, we have the same state of things as if a butterfly's egg gave birth to a caterpillar, from which sprung a string of butterflies soldered to each other, and flying about without being able to separate.

We may here repeat, that Peysonnel, Trembley, Bonnet, and Chamisso were ignorant of the entire importance of their discoveries. Their observations were made on animals too far removed from each other to admit of even a suspicion as to their mutual relations. Besides, they were too isolated, and were not sufficiently numerous for comparison, so that it became impossible to distinguish the essential phenomenon from others which, although more apparent, were not the less accessory.

The problem could alone be solved by modern science, and now the reader is in a position to perceive that these various forms of reproduction, although apparently so very dissimilar, have yet very much in common. As we stated before, we always find that a single germ enclosed in a solitary ovum may give rise to several individuals, even to several generations. It is only of late years that the discoveries were made which established the generality of this law. They embrace the various groups of the lower animals, and mark a new epoch in the history of the subject which should be separately considered.

CHAPTER XVI.

GENEAGENETIC PHENOMENA IN ANNULOSA AND MOLLUSCA.

Hitherto I have been endeavouring to show how the knowledge of geneagenetic phenomena was gradually arrived at. It now remains for me to explain, or rather to describe, how these apparently exceptional phenomena are referable to the most general laws in the scientific scheme. But, before touching on the theoretical portion of my subject, it is necessary to bring forward a certain number of examples, in order to justify conclusions which are occasionally different from those that some of my distinguished colleagues have drawn from the same premises. These examples are especially interesting. We find in them the definitive solution of perhaps the most debated question which has ever engaged the attention of philosophers and naturalists.

It has been already seen that geneagenesis becomes more and more complex as we pass from the Hydra to the Aurelia, and since facts of a similar character are multiplying and presenting peculiarities which are every day assuming more varied features, it becomes necessary for the purposes of study to arrange them in certain groups. This is what has been done by Van Beneden, who proposes to distribute them among five sections. We shall adopt

his plan, just making a few trivial alterations,* and shall regard each one of the foregoing examples as characterizing, by the nature and succession of its developmental phases, one of these five groups. In the first section we shall place the Hydra, and all animals, no matter what their position in the zoologic scale, which propagate in a similar manner; in the second we shall rank the compound Ascidians; in the third the Aphides; in the fourth the Biphoræ; and in the fifth the Aurelia.

It is necessary, too, that in each of these sections, the process of geneagenesis shall always take place identically. In proportion as we obtain an accurate knowledge of these strange phenomena, we observe that each phase of development is in almost every species accompanied by different and occasionally quite unexpected peculiarities. Since it would be impossible here to describe all the facts in connection with this subject, we shall limit ourselves to a *résumé* of the more curious ones which are presented to us by the principal groups of the animal kingdom; and we shall follow the zoological scheme, without confining ourselves closely to Van Beneden's classification. In taking this course we shall only be acting consistently with the plan pursued in other portions of this volume. Besides, we shall by this means expose a result of much importance; we shall show how the phenomena become progressively more complex in proportion as

* In the work in which he proposes these divisions, "La Génération alternante et la Digenèse," Van Beneden places under the third section animals which in my opinion belong to the second. He places the aphides last, although their geneagenesis is far more simple than that of either the Medusæ or the intestinal worms.

we descend in the scale of beings, as though Nature were compelled by the very simplicity of the organisms to multiply the means necessary to ensure reproduction.

In the outset we may state that no vertebrate animal is reproduced by geneagenesis, and that this form of reproduction is very rare among highly organized invertebrates. In the insect class, where the species number a hundred thousand, very few examples beyond those of aphides are known.* About the most remarkable, is that of one of the hymenopterous family, Pteromalidæ (*Ophionurus*),† which was discovered by Dr. Philippi. This insect, like many of its kindred, deposits its ova in the egg

* I agree with Owen, Steenstrup, Van Beneden, Carus, &c., in considering the agamic reproduction of aphis to be due to a process of internal budding. It has been proved by the researches of these naturalists that the reproductive bodies which are developed during summer in the wingless aphides are simple deciduous buds. Leydig, a German naturalist well known through his important writings, believed he had satisfied himself that these bodies are genuine eggs which are hatched within the mother's oviduct. If this view were correct, the aphides would be ovo-viviparous, and it would be no longer a question of geneagenesis but rather of parthenogenesis, which we shall treat of hereafter. But this opinion, which seemed to support Heiden's observations, to which we alluded some few pages back, was refuted by the new and very accurate researches of Leuckart, Lubbock, and *especially* of Huxley, which will be discussed further on.

† "Annales des Sciences naturelles," 1851. The order Hymenoptera includes all insects akin to the bee and which are provided with four membranous wings, and the Pteromalidæ constitute one family of this order. Philippi's observations were at first contested, but he afterwards confirmed them by a series of new researches, in his "Troisième Mémoire sur l'Histoire genésique des Trématodes."—Mémoires de l'Académie des Sciences de Turin, 1857.

of a small coleopteron* (*Rhynchites betuleti*), which does considerable damage to the vine plant, by gnawing the buds, and rolling up the leaves, in order to deposit its eggs in them. From the egg of *Ophionurus* there is developed an infusoria-like animal, which is transparent, has an almost homogeneous structure, presents posteriorly a few bristly segments, and is possessed of a long tail, which it whisks about with rapidity. In the interior of this false larva there is slowly developed a sort of double-jawed worm, which eventually entirely occupies the place of the first animal, and then bursts from the species of case formed by the skin of its parent, and changes into a nymph, which will soon become a perfect insect. This is an instance of the simplest kind. The proglottis is directly produced by the scolex, but it reaches the perfect condition only through a metamorphosis.

Associating this fact with what occurs among butterflies, we may say: From the egg there sprung a naked caterpillar, which produced a hairy one, by a process of internal budding, and this was then transformed into a chrysalis and afterwards into a butterfly.

Of the four classes included in the *articulate* division of the Annulose sub-kingdom, only two—insects and crustacea—are reproduced by geneagenesis; and even among the latter the only example known is that of

* The Coleoptera, commonly called *beetles*, have a single pair of membranous wings, which are covered when at rest by the horny *elytra*.

[Philippi has since altered his opinions, and now regards the peculiar development of Pteromalus as an instance of hypermetamorphosis rather than of development by nurses, as Steenstrup believed.—Tr.]

Daphnia.* Nothing of the kind has been yet observed in the Myriapoda, Arachnida, or Cirrhipedia.

On the other hand, this phenomenon has been observed in many worms—that is to say, among the inferior annulosa. Apart from the helminthes, whose history deserves to be treated of separately, we find it among the annelids, nemertes, and the naïdes—small aquatic beings related to the earth-worms.

Geneagenesis assumes peculiar features in each of the groups which I have enumerated. It was known for a long while under the name *fissiparous generation*, or *fissiparity*. In this process, the animal divides itself into two portions. In certain planariæ and naïdes, this division takes place without any apparent preparation, and each isolated portion produces either a head or tail, as the case may be, by gemmation. The animals thus produced are for several generations neutral like the parent; but eventually, through the operation of conditions of which we are as yet ignorant, the sexes are developed, and the being is propagated by ova. Almost the same thing occurs in a little nemertes which I have often found in the outskirts of Paris; but in it the young being always acquired its head before quitting the parent.

It is similar with Myrianis and Syllis. In these annelids, the creature which has been thus spontaneously created, grows from between the final and

* The origin and development of Daphnia's reproductive bodies have been well described and with considerable detail by Mr. John Lubbock in his excellent "Account of the two methods of reproduction in Daphnia, and of the structure of the Ephippium"—Philosophical Transactions, 1857. I shall examine his conclusions in another chapter.

penultimate rings of the parent's body. In the first there may occasionally be seen as many as six individuals placed end to end, forming a sort of chaplet, the string of which is represented by the intestinal canal which travels from one to the other.* In Syllis, I have never found more than one solitary individual; but to compensate for this, it has very important functions to perform; it alone is either male or female, whilst the parent is simply a neuter.†

Returning to the similé we have so often employed, we should say here of the butterfly, that its egg produced a single caterpillar, which gave rise by spontaneous division to new individuals; but that these were in some instances a series of caterpillars like the first one, and of which a certain number sooner or later became perfect insects, and in other cases were fully-formed butterflies, that remained for some time attached to the parent, and kept flapping their wings in order to effect their escape, which they did subsequently.

In regard to the Molluscan sub-kingdom, there is little to be said. No true mollusk presents any of the phenomena we are now considering. In Molluscoïda, on the contrary, geneagenesis appears to be the rule. As all these animals are more or less akin to the Ascidiæ and Salpæ, we might expect that their mode of reproduction would be analogous; and such a supposition is fully borne out by what is known of their generative processes.

* "Mémoire sur l'Embryogénie des Annelides," by M. Edwards, in the "Annales des Sciences naturelles" for 1845.

† "Mémoire sur la Génération alternante chez les Syllis."—Annales des Sciences naturelles, 1844—"Rambles of a Naturalist."

CHAPTER XVII.

GENEAGENETIC PHENOMENA OF RADIATA.

The three classes—Echinodermata (sea-urchins, &c.), Acalephæ (jelly-fish), and Polyps—which collectively constitute the sub-kingdom Radiata, require to be very fully treated, in order to give a detailed account of the varied and complex phenomena presented in their reproduction. Geneagenesis is seen here in all its phases; and as in many other instances, so in this one, the study of embryogeny, by disclosing unexpected results, put the history of these beings in an entirely new light, and modified received opinions in many particulars. We have spoken of the Hydra and Aurelia already, and we shall now mention some additional facts in support of this assertion. As an example, we shall select from the arborescent, plant-like polyps which cover our rocks and sea-weeds, the pretty *Campanularia geniculata*, whose strange development has been so patiently watched by Löwen;* but we shall now and then explain the results arrived at by the Swedish naturalist,† through the assistance of Steenstrup's writings and those of his followers.

* "Observations sur le Développement et les Métamorphoses des genres Campanulaire et Syncorne." This work, which was first published in Swedish, was afterwards translated into French and German.—Annales des Sciences naturelles, 1841.

† "Uber den Generationwechsel."

From the egg of this Campanularia there springs a ciliated larva, which attaches itself to a solid body, becomes flattened, and then resembles a little cake, which has a cavity hollowed in its substance. In the centre of this, granulations make their appearance, and gradually increase in size, elongate, and are converted into a straight hollow stem, which is soon covered by a transparent horny sheath. The current which traverses the internal canal of the stem accumulates the granules at the extremity of this latter, and develops a true bud, which becomes organized, and assumes the form of an inverted bell, closed at its orifice by a horny membrane. The organized material is soon detached from the inner surface of this structure, and converted into a sort of conical button, from which tentacles are pushed out. Finally, in the centre of this mass there appears an orifice, which eventually constitutes a mouth like that of Hydra. The first polyp is then complete, and, bursting through the membrane, it grows out like a flower which has unfolded its floral envelopes.

This primary polyp is invariably both a nurse and neuter, and its office is to provide food for itself and the future members of the community. These soon present themselves, at first in the bud-form, but afterwards, undergoing the same changes as the first, they constitute an entire colony, which is by no means unlike a little zigzag plant, to whose angles are attached short stalks bearing these food-seeking polyps.

In the axils of the branches there now appears a new series of buds. These buds are at first like the former, but they are attached to a much shorter foot-

stalk, and they grow to a far greater size. The vesicle which results from the development of one of these, is five or six times as large as those above described, and is traversed from end to end by the living tube which enters into all the ramifications of the polypidom. In the covered species it is upon this axis that the *reproductive polyps* are produced, which ensure the perpetuation of the species.

Each of the new productions presents within it, even on its first appearance, one or two well-marked ova; these grow *pari passu* with the original, and become converted into as many ciliated larvæ. As soon as they have reached a certain development, the polyps burst the capsular membrane and appear externally. They then resemble medusæ, minus the digestive apparatus, which they do not require, as they remain in communication with the vital portions of the polypidom, and thus derive nutriment from the materials drawn in by their long-tentacled brethren; besides, their lives are extremely short. The larvæ soon found new colonies at a distance; and now that their functions have been performed, the polyp mothers fade away, and are gradually resorbed.

Although there appears little analogy between the phenomena presented in the development of Campanularia and Aurelia, yet there are very close relationships between them.

In both cases a ciliated larva or scolex is produced by the ovum. It happens, however, in *Campanularia*, that the first polyp is the result, not of a process of metamorphosis, but of one of budding, which produces a being very different from that which preceded it.

Here, then, there is a second generation of scolex—a *deuto-scolex*—which multiplies under its new form of campanularia. The resulting polypidom is in some measure a *compound deuto-scolex*, which develops a strobila, represented by the capsule containing the reproductive bodies. Finally, the latter, plus the ova in their interior, are the proglottides, and correspond to the small medusoids which are transformed into Aureliæ, or even to Aureliæ themselves. There is this distinction, however, between the two: the reproductive bodies of Campanularia are fixed to the polypidom, whilst those of Aurelia are free and floating, and lead an independent existence.

The analogies we have attempted to establish may appear questionable to those who are unacquainted with the whole of the facts; but a perusal of the works of Ehrenberg,* Krohn, Kölliker, Dalyell, Dujardin,† and Derbes, will leave hardly any room for doubt. By studying Van Beneden's splendid memoirs on Campanularia and Tubularia‡—notwithstanding the errors in determination which the author has since corrected—it will be seen that facts which are apparently devoid of analogy are associated undeniably by a host of intermediate ones.

It is very necessary, in a study of this sort, to point out, in the commencement, the circum-

* "Corallenthiere des rothen Meeres," 1834.

† "Mémoire sur le Développement des Méduses et des Polypes Hydraires."—Annales des Sciences naturelles, 1845. The chief results of this admirable memoir have been detailed in my "Rambles of a Naturalist."

‡ "Mémoires de l'Académie de Bruxelles," 1843 and 1844.

stance of extreme variety in the phenomena exhibited.

In the case of the lower forms of animal life, Nature seems, as it were, to despise that uniformity in embryogenic laws which is so characteristic of the development of the higher groups. We find the most decided differences between the developmental processes of even species of the same genus. Thus, according to Löwen, the medusoid proglottis of one campanularia remains attached to the polyp which gave it birth; whilst it is stated, on the authority of M. Desors, that in another species — the gelatinous Campanularia—it bursts the reproductive capsule on arriving at the same condition, and swims about freely, undergoing its metamorphosis in the surrounding water.* It was also observed by the same naturalist, that some of the polypary's branches produced only male, and others only female, reproductive bodies. In fact, the greater the advance made in the field of discovery, the larger the field appeared to be, and the greater the number of new points of view which it presented. We shall now endea-

* "Lettre sur la Génération Médusipare des Polypes hydraires." —Annales des Sciences naturelles, 1849. I am sorry that I cannot quote some of the passages from this memoir, especially those regarding the difference between the author's observations and those of Saars on the development of Aurelia. Desors saw the proglottis (the fully-formed Medusa) produced by gemmation from the interior of Scyphistoma (the Medusa in the hydroid state), and lifted up in piled form, from the mouth of the polyp, which remained, after entire separation of the proglottides. As the matter is one dependent on plain observation, it seems to me that both naturalists may be right, and that these differences may be adequately explained by supposing a difference of species.

vour to place our readers in a position to observe some of them.

From the preceding remarks we may conclude that the relation of polyps to acalephs is far more intimate than it was thought to be fifteen or twenty years ago. The most recent researches tend still more to break down the formerly established distinction between the two classes. For example :—

Among the strange creatures which inhabit the ocean, may be mentioned the name of Stephanomia. This is actually a living garland of animals; it has flowers like the most lovely enamel, and filaments like crystal, which are attached to a transparent stem, surmounting a vesicle filled with air, that plays the part of a *float*. This strange being may be regarded as the type of Cuvier's group of *Hydrostatic acalephs*, a group which was afterwards styled *Siphonophora* by the German naturalist Escholtz. Zoologists were for a long while in a state of doubt regarding the nature of these beings. Vogt* and Leuckart,† who were led back by a careful investigation to the views of the distinguished naturalist traveller Lesueur, put forward the view that they were compound polyps; and this idea has been fully confirmed by the writings of Huxley,‡

* "Ocean und Midlmeer," 1848.

† "Mémoire sur la Structure des Physalies et des Siphonophores en général," 1851, also in the "Annales des Sciences naturelles," 1852. This—Leuckart's first memoir—related to animals which had been preserved in spirit. He has since completed and extended his researches in a new memoir, which forms part of his "Zoologische Untersuchungen," 1853.

‡ "On the Structure of the Acalephæ."—Philosophical Transactions, 1851.

Kölliker,* Gegenbaur,† and Vogt;‡ and by our own researches also.§

Hence we should expect to find the different forms of reproduction, before described, occurring among the Siphonophora; and such in fact is shown to be the case, by the series of investigations we have just referred to. There we observe geneagenesis in its most complete and varied forms. Yet its final term is almost always a medusiform animal, sometimes long-lived, sometimes short, with an organization frequently of a very simple character, but occasionally more complex; in some instances free and floating, as in the Aurelia, in others fixed, as in the case of Löwen's Campanularia, and which *alone* assumes the sexual attributes, male and female, and reproduces itself by ova. We conceive it to be useless to introduce the analogy we have so often employed, and to contrast that which occurs among the Siphonophora with the simple metamorphoses of the Lepidoptera.

Looking at this multiplicity of phenomena, all coming within the same scheme, one might feel inclined to believe that geneagenesis, in spite of all the complications to which it is liable, is a general law for all the groups we have named; that all polyps spring from a medusa, and all medusæ originate in polyps which have reached their final condition of development. But—and we cannot repeat it too

* "Die Schwimpolypen oder Siphonophoren von Messina," 1853.

† "Beiträge zur nähren Kenntniss der Schwimpolypen," 1854.

‡ "Recherches sur les Animaux inférieurs de la Méditerranée," first memoir, on the Siphonophora of the Sea of Nice, 1854.

§ "Mémoire sur l'Organisation des Physalies."—Annales des Sciences naturelles, 1854.

frequently—it is necessary to institute many investigations before generalizing, in regard to the lower forms of animal life. It has been shewn by Krohn and Lacaze du Thiers, that certain medusæ and polyps are reproduced directly, and by a simple metamorphosis. The first proved that the larva of *Pelagia noctiluca* becomes an acaleph without assuming the polyp form ;* and it was demonstrated by the second, that neither the sea-anemones, nor corals and their kindred, give rise to medusæ.† When science is concerned, well-proven exceptions are as valuable as the discovery of a new series of geneagenetic phenomena.

Leaving the Medusæ and Polyps, we come to a group of beings whose real nature is still somewhat involved in obscurity—the *Infusoria* and *Sponges*, united under the name of Protozoa. Here again we meet with geneagenesis. Unfortunately, the observations which it is necessary to make in following an animal through the progressively complex phases of its existence, present in this instance many difficulties, which, in consequence of the extreme minuteness of the creatures to be investigated, are too frequently insurmountable. Nevertheless, we shall

* "On the earliest stages in the Development of Pelagia noctiluca."—Annals of Natural History, 1856.

† "Comptes Rendus de l'Académie des Sciences," 1859 and 1861. In the sea-anemones there is but a *metamorphosis properly so called*. The ciliated larvæ are transformed into perfect animals, and each of them proceeds from a single egg and produces but one individual. In the coral, the ciliated larva gives birth to an entire colony. In this case then, there is *geneagenesis*, but the phenomenon is reduced to its simplest condition, since the colony produces directly both eggs and larvæ.

endeavour to separate the general and best-ascertained results, from the chaos of numberless contradictions presented by the writings of those most distinguished in this branch of study.*

The sponges are truly compound animals, although it would be very difficult if not impossible to distinguish a single individual. These beings, whose position is still regarded by some naturalists as problematical, possess a framework which is either horny or calcareous, and is frequently represented by a network of simple spines or spicules. There is spread over this form of skeleton, a sort of organized varnish or coating, which extends to the very smallest ramifications. This varnish is really the living matter which constitutes the animal; and each species, although having the elements common to all, is as variable in form and proportions as a polyp colony.

Like the latter, the sponges can be reproduced both by gemmation and fissuration. Grant's† obser-

* Notwithstanding the many improvements which the microscope has undergone for the last thirty years, it is still far from supplying the wants of Histologists. In order to become accurately acquainted with many details, it would be necessary to have a magnifying power of from ten to twelve hundred diameters, with the same clearness and definition as one of three or four hundred diameters. My opinions on this matter are as decided as they were twenty years ago, when I was engaged in the study of this group. Of all my researches on this subject, I only published a short note which was addressed as a letter to M. Dujardin, and which he inserted in his article on Infusoria in D'Orbigny's dictionary (1846), although it was in opposition to his fundamental views. This note seems to have been unnoticed by most naturalists who have since written upon this subject, among others by MM. Claparède and Lachmann.

† Grant's writings date from 1826, and appeared in the "Edinburgh New Philosophical Journal."

vations, which were confirmed by those of Audouin and Milne Edwards, and the researches of other naturalists, prove that ciliated larvæ, like those of infusoria, make their escape from within. In Spongilla, which is a fresh-water genus, very common in the neighbourhood of Paris, and which was for a long while looked on as a plant, this form of reproduction was observed by M. Laurent to occur during the entire summer. But, in the autumn, the Spongilla's tissue becomes filled with small roundish bodies of a yellowish-white colour, enclosed in a very resisting envelope: these have been regarded as grains, and have been termed by Laurent *internal germs*. They survive the destruction of the surrounding parenchyma, and give rise in spring to as many spongillæ, which in their turn produce others by the processes above described. The nature of the germs to which we have alluded was for a long period as undecided as their origin was imperfectly known. The problem, however, was eventually solved, and still more important truths revealed, by M. Lieberkühn, in a memoir which received the French Academy's prize.* This

* The subject given by the Academy in 1854 for a prize essay was that of "The Reproduction and Metamorphoses of Infusoria;" and the prize was divided between M. Lieberkühn's work and that which was presented jointly by MM. Claparède and Lachmann. The latter memoir has been published, and forms the second volume of the "Études sur les Infusoires et les Rhisopodes." It is much to be desired that M. Lieberkühn's work may be also published. M. Lachmann died since that period, at a very early age, and M. Claparède has briefly noticed the event, at the same time expressing the sorrow of a friend who has lost the companion of his studies, and the regret of a savant who sees the field of science deprived of a man of genius, whose great talents promised far more than his brief lifetime permitted him to accomplish.

naturalist detected in Spongilla the distinction and fundamental characters of the two sexes—the male and female elements. The ova which he described were clearly characterized by the existence of the three concentric spheres, and were, according to him, transformed at first into non-ciliated embryos. These are the grains of the older writers, and the *internal germs* of Laurent, who saw them, give rise directly to spongillæ. But a certain number, if not all of them, undergo new modifications, become covered with cilia, and thus by travelling to a distance from their birth-place, distribute the parent species. Each of these ova, therefore, is capable of producing, not only one but very many individuals, which proceed indirectly from it, but directly one from the other. Consequently, we may class Spongilla, and doubtless all sponges, among the animals which are reproduced by geneagenesis.

We may say the same, and with far greater reason, of the Infusoria.

The existence of the sexes in the Infusoria, the production of ova in these microscopic organisms, and especially the presence of the male element, have been actively debated on many occasions. Ehrenberg, whom we may call the re-discoverer of the world of microscopic animals, admitted these three facts as the results of his observations. On the other hand, our skilful micrographer, F. Dujardin, who devoted himself specially to the Infusoria, and who regards them as composed exclusively of *sarcode*, rejects the whole three.

Naturalists waver between these two extremes; it is quite true, as Messrs. Claparède and Lachmann have

pointed out in their splendid treatise, that strange blunders and mistakes have been made by some of those whose views more or less resembled those of Ehrenberg. However, my own personal observations have always compelled me to admit the existence of reproductive bodies, which play the part of eggs, and whose minuteness alone prevented my perceiving very distinctly the three constituent parts.* At present there is no room for doubt either on this point or on the others. In those beings, which, as regards size, approach the lowest bounds of organic development, modern science has, after much hesitation, definitively proved the existence of all the essential phenomena of normal reproduction. The Infusoria, like Mammalia, Birds, Mollusks, and all other animals, deposit ova which are characterized by the presence of three concentric spheres. As in all other species, these ova cannot be fertile till they have been influenced by the male element, but, when this has operated, the germinal vesicle and spot disappear, prior to the conversion of the yelk into a new being.

These facts were at once the most important in a scientific aspect, and the most difficult to prove. Perhaps one of the greatest benefits which has been conferred on general physiology, is that which has been rendered by a young French naturalist, M. Balbiani, who has placed these facts beyond all discussion, and caused them to be accepted by those who appeared least likely to admit the existence of normal reproduction among infusoria.†

* "Revue des Deux Mondes," 1856.

† Before M. Balbiani's publication, there had been but one or two very incomplete treatises on this difficult subject. One was

The Infusoria are not reproduced by ova alone; indeed, this is apparently their rarest form of propagation, for it appears only after the other modes, and these were known long before it. As early as the year 1765, Charles de Saussure observed that they multiplied usually, by a peculiar process of *spontaneous division*, by which two individuals were produced, which exactly resembled the single one from which

that of the illustrious Jean Müller (1856), referred to in the works of Lieberkühn, and Claparède and Lachmann. The two latter made similar observations some short time after (1859). Both discovered in the bodies of certain *Paramecia*, filaments which were decidedly analogous with those in the fecundating element of all animals. But neither of them determined the organ from which they proceeded, and neither of them detected the peculiar movements of these corpuscles. Nevertheless both admitted the possibility of the union of the sexes in Infusoria, and this conclusion was accepted by the Academy ("Rapport sur le grand Prix des Sciences physiques pour l'année 1857," by M. de Quatrefages). M. Balbiani showed that the sexes were united in the Infusoria, and that the enigmatical bodies which Siebold termed nucleus and nucleolus, were really generative organs, distinguished by the products to which they gave rise. He described the modifications which each undergoes when it enters upon its function, and he also demonstrated the changes which take place in the ovum after impregnation. Part of M. Balbiani's statements has been verified by myself and the remainder has been accepted in its entirety by M. Claparède, who, in the notes added in 1860 to his "Études sur les Infusoires," renders ample justice to the valuable results arrived at by M. Balbiani. The latter naturalist's writings have appeared in the "Comptes Rendus," 1858—1860, and in the "Journal de la Physiologie de l'Homme et des Animaux:" most of them have been collectively published under the title of "Recherches sur les Phénomènes sexuels des Infusoires," 1861. On his part, Stein, who has published many beautiful memoirs upon the history of Infusoria, appears to have arrived at results in accordance with those of M. Balbiani (Claparède); but I regret to say I am unacquainted with the work which he has just published.

they were formed.* Modern researches have only substantiated these ideas; for example, it has been demonstrated by Siebold and Stein, that the *nucleus* and *nucleolus* [the reproductive organs according to Balbiani] are, like the other portions of the body, divided between the two offspring, each of which is actually half of its parent.

The Infusoria are reproduced by *external gemmation* also, after the fashion of the Hydra; † and in addition, we find the *internal budding* which is characteristic of the Aphides. In the Infusoria, as in the insects alluded to, it is upon the egg-producing organ (nucleus), and frequently at its expense, that the embryo is formed. Siebold was the first who pointed this out,‡ but its entire value was not understood, and indeed the observations were themselves forgotten, when Focke, Cohn, and Stein published *theirs*, which, on the contrary, were received with interest.§ From the immense number of memoirs published by the last-named authors, we are enabled to conclude that this form of reproduction is as general among Infusoria as that of *fission*.

* Saussure was the first who regarded *fissuration* as a usual method of reproduction (Dujardin "Histoire des Infusoires"). Trembley made accurate observations on the *Vorticella* and *Stentor*, twelve years before ("Études sur les Infusoires"). In Messrs. Claparède and Lachmann's work, the details of the physical characters of this mode of reproduction are very precisely stated.

† This has been long known. The phenomenon was investigated by Spallanzani in 1776, and since his time by a great many observers; among others by Ehrenberg and Stein. New facts have been added by Claparède and Lachmann, to those discovered by their predecessors.

‡ "Helminthologische Beitraege."—Wiegmann's Archives, 1835.

§ For the entire history of this matter, I can hardly do better than refer the reader to Messrs. Claparède and Lachmann's volume, from which I have borrowed most of the above details.

Nevertheless, it is well to be on our guard against various sources of error. Occasionally, certain organs, or even the entire bodies of Infusoria, are attacked by parasites, which, as they pass away, are sometimes regarded as the offspring of the animal which they are really victimizing.* It seems to me that M. Balbiani's discoveries will necessitate a careful revision of the facts attributed to internal gemmation. It may be that in certain cases, the fragments of the *nucleus* which have been hitherto looked on as destined to the *direct* formation of the embryo, pass in reality through the condition of ova, which are afterwards hatched within the substance of the mother, as among all viviparous animals.

But whether the embryo proceeds directly from the ovary, or results from the transformation of an ovum produced by it, it is quite unlike its parent when it first starts in life, and has to undergo a series of metamorphoses. In what do these consist? Here, unfortunately, we are placed among uncertainties and contradictions, and even what was believed as incontrovertible a few years since, is now either questionable or proved to be erroneous.

* Some of these instances of parasitism have been made known by Claparède and Lachmann. Balbiani has also drawn attention to this matter, by a note in which he shows that the *Acineta parasites* which become introduced into the bodies of various Infusoria, and especially into those of Paramecia, have been mistaken for embryos formed by internal gemmation. This fact furnished the French naturalist with a new argument against Stein's theory, the reproduction of Infusoria by *acineta-forms*—which has been justly opposed by Claparède and Lachmann in the "Comptes Rendus", for 1860.

Comparing the writings of Pineau,* Pouchet,† and Stein,‡ and admitting that the facts upon which these observers agree are true, we are led to regard the changes of form as exceedingly numerous. If we associate some of these with the facts announced by Jules Haime,§ we shall see that these alterations are still more numerous, and the Infusoria may be then considered the group in which the metamorphoses which a single species may undergo are carried to their greatest length. Such in fact was the opinion I myself put forward when first engaged in the study of these complex questions; but later discoveries, and especially those of Claparède, Lachmann, and Balbiani, induced me to modify it.

Have not the two first writers whom I have mentioned gone into the other extreme? According to them, the metamorphoses of ciliated infusoria in general are most probably of a very simple character. The embryo, which is not very unlike the parent, has to undergo but slight modifications in acquiring its definitive form.‖ This conclusion is at all events a premature one. It is based exclusively upon a very

* "Annales des Sciences naturelles," 1845—1848.

† "L'Institut," 1849.

‡ Stein's first writings date from 1849; they appeared in various German magazines, and were in part reproduced in the "Annales des Sciences naturelles."

§ "Observations sur les Métamorphoses et l'Organisation de la *Trichoda lynceus* (*Aspidisca lynceus*, Ehrenb.)."—Annales des Sciences naturelles, 1853.

‖ The transformations of the *Acineta* embryos have been all observed by Cienkowski, Claparède, Lachmann, and D'Udekem; but none of these writers have extended the same form of researches to the other groups ("Études sur les Infusoires").

small number of facts, observed by four naturalists, in a *single* and very limited group of this extensive class. Are generalizations framed in a similar manner in all cases? It would form a very marked exception to what we have seen elsewhere. From all that we know of Insects, Mollusks, and Radiata, or even of so limited a group as that of Batrachia, we are justified in believing that, in the Infusoria likewise, the metamorphoses present various and complex phenomena which remain to be discovered.

This view is further borne out by Jules Haime's observations upon *Aspidisca lynceus*. I am aware that M. Claparède declares them to be erroneous from beginning to end; but then, he has not repeated them himself, and notwithstanding the decided tone of his condemnation, we cannot accept his opinions till he has brought forward some proofs in support of them.*

* In speaking of Jules Haime, M. Claparède thus expresses himself, in a note of four lines appended to the splendid work I have so often alluded to. "There has evidently been a series of confusions, the result of which has been the co-ordination of organisms which have actually no relationship to each other." This is exactly what was said of Küchenmeister's and Van Beneden's first researches on the intestinal worms. It is well known what happened to this hasty condemnation. I cannot think that Jules Haime's work is as unworthy as M. Claparède imagines. The conscientious manner in which this young naturalist laboured is well known, and I am personally aware that the memoir in question occupied a very considerable portion of his time, and that he took the greatest precautions to isolate the objects under observation, and to avoid all possibility of mistake. Do such care and pains usually terminate in but a *series of confusions?* Certainly the thing is *possible* in such instances. The history of science generally, and of microscopic science in particular, shows us too frequently that it may be so. But it would be only simple justice to begin by endeavouring to

According to Jules Haime, the infusorian described under the name of *Oxytricha gibba* is but a transition form; and even in reaching this condition, it has to undergo other transformations.* Be that as it may, Haime saw the Oxytricha reproduced by fission, and he observed that at a given moment the individuals thus produced became more and more inactive, became contracted, and even encysted in a sort of flexible shell secreted by the integument. At this period the Oxytricha is but a small mass of living matter, without a trace of organization, and enclosed within a sphere which is about three-hundredths of a millimetre in diameter. In the interior of this mass movements take place, which, though imperceptible to the eye, make themselves apparent by their results.

By degrees, numbers of irregular granulations grow from this species of ball; a small cavity is developed in the interior, and vibratile cilia begin to make their appearance; new changes take place; the internal

satisfy *one's self*, and this is exactly what M. Claparède does not appear to have done; for he alludes nowhere to contradictory observations, and assuredly he could not fail to be acquainted with them, did they exist.

Jules Haime is no longer here to defend himself. He, too, was taken from among us at an early age, leaving upon the minds of all who were acquainted with him, or who had only studied his numerous writings upon various branches of natural history, the stern conviction that science sustained a serious loss by his removal from the field of labour. I have merely discharged a duty, in defending a work which cost him much time, and upon which he bestowed great care. No one could more fully appreciate this than Lachmann's former friend.

* According to M. Pineau, the Oxytrichæ are the result of the metamorphosis of certain Vorticellæ; but this statement certainly requires to be proved anew.

portion of the mass divides into two parts, one alone of which possesses life; and soon the new being, abandoning the lifeless part, leaves its temporary prison, in the form of an ovoid infusorian, about one-third as long as the Oxytricha. In this condition it belongs to the genus Loxodes of special zoologists. After having lived for some time in this condition, it again assumes the ball-form; an abundant secretion is poured out over all parts of its body, and the mouth appears as a small oblique slit; a proportionally very long and thick filament is pushed out from its side, and four or five others show themselves posteriorly; the body, convex above and almost flat below, is covered with large wrinkles, and the infusorian moves about with great rapidity, sometimes swimming by the aid of the cilia, and at others walking with the help of the filaments, which play the part of feet. Under this form, which is certainly very different from those which it before presented, it was known to the older writers as *Trichoda lynceus*.

In concluding his memoir, Haime asks whether the condition of *Aspidisca* (Trichoda) is the final one assumed by the *Oxytricha*, which was the starting-point? We are justified with him in doubting that it is so. The *reproductive bodies* which are at present regarded even by M. Claparède as the true ova, were never found in *Trichoda* by this accurate observer. Therefore, from what we have already seen, and from what we shall see more forcibly hereafter, it results that an animal which undergoes metamorphoses should not be considered adult till it has clearly presented the sexual attributes. It seems to me that this rule should be accepted as an *absolute* one. It should be

applied to the Infusoria as well as to other animals. Consequently the Trichodæ, like other species, can only be definitively regarded as perfect animals when the existence of these attributes has been proved in them.*

Notwithstanding that uncertainty which time and study will eventually do away with, science is in possession of facts enough to prove that true metamorphoses, stages of transformation, and the various phenomena of geneagenesis occur among the Infusoria. The first are exceedingly simple. Let us, for example, borrow from Messrs. Claparède and Lachmann's work, the history of those presented by the *Vorticella tuberosa* of Müller (*Podophrya quadripartita* of Claparède and Lachmann), one of the most beautiful species of the Acinetinean group.

This Vorticella or Podophrya is a stationary being. Its body is like a quadrangular pyramid, with very rounded edges. The summit is prolonged into a cartilaginous stalk, twice as long as the body, and is attached to some adjacent body. At each of the basal angles of this pyramid is a sort of papilla, from which spring several filaments, which apparently terminate in small button-like processes. These filaments are really at the same time mouths and arms, and are always extended in a radiate manner. Sometimes if a far larger and more powerful Infusorian passes in the neighbourhood of this creature, it is instantly seized, entangled in the filaments, which then appear to become solid, and the terminal button-

* I am quite aware that, in thus expressing myself, I am asking for a revision of almost the entire class. But in these times especially, science should not recoil from such an undertaking.

like organs, which are real suckers, are attached to various portions of its body; if then the prey is sufficiently weak to admit of being devoured upon the spot, we can, with the aid of the microscope, see the granules passing from its body into that of the Podophrya.*

This infusorian sometimes produces a great number of small embryos, but at others it gives rise to a single one, much larger than itself. † The latter, at the period of birth, is a little ovoid transparent body, constricted at the middle, and carrying at this point a sort of girdle, which consists of several rows of vibratile cilia. By means of this apparatus it swims about in the liquid, rapidly enough at first; but after a few minutes this wandering propensity is lost. The *larva* arrests its movements now and then, as though desirous of rest, and eventually becomes permanently fixed. Its cilia, henceforth useless, disappear, the suckers begin to present themselves, and the footstalk exhibits itself, and is rapidly prolonged. In the course of four hours the *Podophrya* has acquired its definitive form, and has now only to increase in size—to grow.

If the animal which we have followed from its birth were now complete, it would be a case of simple metamorphosis. But the Podophrya which has been thus formed, gives rise to new individuals by sponta-

* I have given unhesitatingly, but in an abridged form, the details supplied by Messrs. Claparède and Lachmann, for, without having gone as far as they, I observed a quite analogous state of things.

† The first appears to me to be one of those facts which (subject to consideration) might be associated with true *ovo-viviparity*.

neous division and by gemmation;* hence we here see geneagenesis with all its peculiar features.

The Podophryæ are simple animals; but in the Infusoria, as in the Zoophytes, there are many species which live in colonies, and cover with a miniature arborescence submerged aquatic plants, and the shells of fresh and salt-water mollusks, which thus travel about laden with this living moss. Let us see how these things occur in the case of the *Epistylis plicatilis*. This is one of the commonest and best known species, and has been specially noticed by the two skilled micrographers from whom we have quoted so extensively.

From the body of one of these animals there springs an embryo, a *larva*, of an elongate almost cylindrical form, and supplied with a girdle of vibratile cilia. Placed in a few drops of water, which to it, and to the eye, assisted by the microscope, are almost an ocean, what becomes of it? Direct observation tells us nothing in this instance; but with Claparède and Lachmann we may say, *it is more than probable* that it acts like the larva of Podophryæ—that it attaches itself at some suitable point, and is at first metamorphosed into a simple Epistylis.

At this period the larva assumes a more or less elongated conical form; its extremity, which is slightly expanded, is provided with a circular hood, sloping toward the mouth; a band of vibratile cilia crowns the internal border of this hood, and by its movements produces a series of currents which carry the nutritive corpuscles to the animal's mouth. The

* Claparède and Lachmann first demonstrated this latter mode of reproduction in the species referred to.

body is borne upon a straight cylindrical stem, expanded at its base, and which seems a little tube of the purest crystal.

Our Epistylis does not remain long in an isolated condition; nor does it give rise to the new members of the future colony by budding merely, as is the case among the Campanulariæ, but by *fission* also. The single individual resulting from the metamorphosis of the larva divides itself completely into two parts; each of these halves remains attached to the parent stem, undergoes its completion in that position, and develops posteriorly a smaller stem, which gradually elongates. We may say it is a sort of fork, each prong of which is terminated by a living being. After a while, each of these secondary branches divides in its turn in a similar manner, and so on, until from the first Epistylis there is produced a crystal tree, whose divisions are perfectly regular, and all of whose branches attain exactly the same height.*

The individuals thus formed by division are not all destined to be constantly motionless. We occasionally find that certain of them exhibit a constriction of the posterior portion of the body; a circular groove is gradually formed, and its borders are furnished with long vibratile cilia; the division becomes deeper and deeper, and finally the Epistylis drops from its stem like a wall-fruit. But it is not destined to remain at the root of the tree from which it falls. Thanks to the locomotive apparatus which is placed posteriorly, it swims about with as much facility

* The cluster of Epistylis has often been compared to flowers which present a *corymbose* inflorescence.

as the ciliated larva did. However, it very soon abandons this wandering existence, attaches itself once more, loses its vibratile cilia, employs its buccal apparatus, which till then had been carefully folded up, and soon elevated upon a new stem, which has been developed from behind it, becomes the starting-point of a new colony.*

If we were writing a history of the Infusoria, we should have much to say on the subjects of *encystment*† and *conjugation*.‡ These two phenomena are doubt-

* In treating of the formation of the stems of Epistylis, most authors use expressions which seem to imply that these stems have no share in the vitality of the individuals. I believe, on the contrary, that the stems are living organisms. In support of this view, I may mention that they are the seat of phenomena which cannot be explained by the adoption of any other opinion. Such are : the increase in diameter as well as in length, the widening of the base, the appearance of the central canal, described by Claparède and Lachmann, and which I myself have observed, &c.

† We apply the term *Encystment* to that act by which an Infusorian surrounds itself with a solid shell secreted by itself, and which places it beyond the control of external influences. Any cause which brings about a result disagreeable to the animal, and especially the evaporation of the drop of water in which it was placed for examination, determines Encystment. Certain species also appear to encyst themselves, in preparing to undergo spontaneous division. Stein especially investigated the phenomenon from this point of view ; and finally it has been shown by Claparède and Lachmann that certain species *encyst* themselves in order to digest their captured prey more easily. Such is the case with *Amphileptus meleagris*, which is nourished at the expense of Epistylis, and whose curious mode of capturing its prey has been described by the writers just alluded to.

‡ *Conjugation* or Zygosis, discovered by Kölliker, and since investigated by most micrographers who have devoted themselves to the study of Infusoria, is a phenomenon by which two, or a greater number of individuals of the same species, appear to became fused, so to speak, into one. M. Balbiani thinks that it is only an illusion

less associated, at least in certain cases, with the class of phenomena under discussion; but occasionally they have only very distant or accidental relations with reproduction, and we shall, therefore, confine ourselves to pointing them out.

We reserved our comments on the history of *Echinoderms* for the last, although this class, which comprises the *Holothuriæ*, the *Sea-urchins*, and *Star-fish*, should be properly ranked at the head of the true Radiata.* We have not done so without a reason. Some naturalists deny that there is any fundamental analogy between the phenomena presented by these animals and those whose history we have just been sketching. Others have expressed doubts on the same subject. Whoever has thoroughly understood what we have endeavoured to convey by the term geneagenesis,—whoever will admit, with us, that the fundamental character of this mode of generation is the production of several distinct individuals by the aid of a single primitive germ, will not have a moment's hesitation; but he will at the same time understand that the exceptional nature of the development of Echinoderms is due to the combination of the phenomena of geneagenesis with those of simple metamorphosis.

The curious phenomena we have indicated have been seen by several observers only of late years. In 1844 Saars—whom we always find at the head

resulting from the imperfection of our instruments, and caused by the intimate approximation which takes place at the moment of the reciprocal fecundations of adult individuals.

* The zoologist will perceive what an artificial arrangement the above would be: the star-fish and hydra are as little akin as man and the oyster.—Tr.

of the list of modern naturalists when we refer to marine animals—described the development of two *Asterias* (*Asterias sanguinolenta* and *Asteracanthion Mülleri*). He saw these Echinoderms, contrary to the rule among animals so low in the scale, absolutely, in some measure, hatch their own ova. He proved that the larva springing from the latter, at first resembled an infusorian, and afterwards presented the appearance of an animal composed of two lateral symmetrical halves, which at a later period became converted into a radiated creature.* Shortly after, the celebrated embryologist Baër tried the effect of artificial fecundation on the sea-urchins, but was only able to observe the earlier stages of development.† Almost at the same period two inhabitants of Marseilles, Messrs. Dufosse‡ and Derbès,§ observed nearly similar phenomena in the sea-urchins; but the figures of the second are very different from those of Saars. Two Norwegian naturalists, Koren and Danielssen, discovered at this period that the *Bipinnaria asterigera* was a developmental phase of the true *Asterias*.‖ Finally, in 1845, J. Müller, the celebrated Berlin physiologist, investigated the marine animals of the North Sea at Heligoland; described

* "Mémoire sur le Développement des Astéries," translated in the "Annales des Sciences naturelles," 1844.

† "L'Institut," 1845.

‡ "Observations sur le Développement des Oursins," in the "Annales des Sciences naturelles," 1847.

§ "Observations sur les Phénomènes qui accompagnent la Formation de l'Embryon chez l'Oursin comestible," 1848.—Annales des Sciences naturelles.

‖ "Observations sur la Bipinnaria asterigera," printed in Swedish in 1847, and translated into French in the same year.

Pluteus paradoxus; followed up his researches in the Mediterranean and Adriatic; and in 1848 commenced a series of publications, which added another chapter to the history of the development of animals.*

Like all his predecessors, Müller saw that the Echinoderms deposited ova from which ciliated larvæ were produced.† These larvæ are spherical at first; then they become elongated, acquire a calcareous framework, formed of long and slender branches, and assume the strangest forms, being sometimes like a painter's easel, and at others like a double ladder without rungs. The arms are in some instances covered with vibratile cilia, but in others the latter are arranged in tufts, and are of service in the locomotion of these peculiar beings, which swim about with considerable rapidity. All these have a complete digestive apparatus, with a large and distended stomach. It is upon the very walls of the latter organ, and upon one of its sides, that the future echinoderm begins to show itself. In the sea-urchins and the Ophiuridæ it appears as a circular flattened disk, which seems to mould itself, as it were, upon the stomach, and

* "Ueber die Larven und Metamorphose der Echinodermen." Six fasciculi appeared at different intervals; they were very carefully analyzed by M. Dareste in the "Annales des Sciences naturelles," for 1852 and 1853.

† This mode of reproduction, however, is not general among Echinoderms. Certain species of the *Ophiuridæ*, animals closely related to the star-fish, are ovo-viviparous. This I ascertained in 1842.—(Comptes Rendus Hebdomadaires de l'Académie des Sciences.) I took from the abdomen of a single mother, six perfectly formed young, which, when placed in vessels of sea-water, lived as though they had been born naturally. More importance is, I believe, given to this observation in the works of my *confrères* who have met with very different phenomena in other species.

soon completely envelops it. As it grows, this disk assumes a radiate form; gradually the *ambulacra* and *spines* present themselves; then the mouth opens externally, always on the lateral surface of the larva. The latter is partly resorbed, and partly laid aside, when the new animal is fully formed. In most Asteriæ these things occur in a similar manner, but in others the larva (*tornaria*) is completely absorbed by the Echinoderm developed within. In the Holothuriæ the tentacular crown is developed upon the larva's stomach, but most of the organs immediately employed are completed and acquire their final characters by a simple *transformation*.

We cannot dwell here upon all the remarkable features of this mode of development. We shall, therefore, confine ourselves to those matters directly related to the subject.* From the sea-urchin's egg there is produced a sort of infusorian, which is metamorphosed into a *pluteus*. In the interior of the latter there is developed an animal of quite another nature. Here we have two very distinct generations produced by different processes, yet both owing their existence to a single primitive germ. This, then, is a case of geneagenesis.

But what here characterizes this phenomenon are the loans, so to speak, which the second generation gives to the first. In all the species which we have hitherto examined, the bud merely borrows the

* We desire, however, to call attention to the exceptional fact of an animal which is destined to become *radiated*, beginning its career with a *bilateral* symmetry like that of the Annulosa. It is the only exception to the embryogenical rule which we have always maintained.—Souvenirs d'un Naturaliste.

materials necessary for its growth, from the parent; it abstracts its nourishment, but it tends more and more to become an isolated being. Whether the operation takes place externally as in Polyps, or internally as in Salpæ, the phenomenon is essentially the same. In the Echinoderms, on the contrary, the bud in the course of growth, surrounds the existing organs and appropriates them. Viewed as a whole, the process of gemmation is one of geneagenesis; but the stomach in Sea-urchins and Ophiuridæ, and the entire digestive apparatus, and some other organs in Holothuriæ, are submitted to a simple metamorphosis only.

The development of Echinoderms forms a sort of connecting link between these two classes of phenomena, and prevents one of those leaps to which Nature ever seems to be so averse.*

* M. Édouard Claparède has come to a similar conclusion on this subject, although we have investigated the matter from very different points of view.

CHAPTER XVIII.

GENEAGENESIS IN THE HELMINTHES OR INTESTINAL WORMS.*—SPONTANEOUS GENERATION.

THE animals we have been treating of, up to the present, are of interest to the ordinary reader as well as to the naturalist. The living blossoms of a polypidom, and the garland of a Stephanomia, are admired alike by the child and the philosopher. We come now to speak of very different beings, whose name even creates an

* The French Academy at its sitting on the 22nd of March, 1852, offered the great prize of the physical sciences for the decision in 1853, of the following question :—"*To demonstrate by observations and experiment the mode of development of intestinal worms, and of their passage from one animal to another, and to apply the anatomical and physiological facts thus proved to the determination of their natural affinities.*" The great difficulties which the question presented, and the short period allowed for its solution left some doubt as to the presence of competitors ; but two naturalists, prepared for a long while, replied to the Academy's appeal. Van Beneden, professor of zoology in the University of Louvain, and Küchenmeister, a physician of Zittau, sent in essays ; that of the first was a genuine work, where the history of Helminthes was treated of in all its relations, and was accompanied by an atlas containing nearly a thousand original figures ; that of the second was a very important memoir, and was likewise accompanied by plates. Upon a very extensive report which I made in the name of a commission appointed to decide the merits, the Academy awarded the prize to M. Van Beneden, and an honourable mention to M. Küchenmeister. It decided also that Van Beneden's work should be printed at its expense. It appeared under the title of "Mémoire sur les Vers intestinaux," 1858.

instinctive feeling of disgust. If the reader desires to follow us, we shall spare him the technical details in endeavouring to convey some portions of a history, which touches on the most important questions in general and philosophic physiology.

Until of late years the term Helminthes had been exclusively applied to those worms which remain concealed within the bodies of other animals. At present this limitation does not exist. It is known now that these internal parasites have very close relations among external beings. The Nemertes and Planariæ are nearly akin to the *Trematoda*, of which we shall speak presently. These affinities which have been but recently observed, have caused the Helminthes to be no longer ranged among the *Radiata* where Cuvier placed them, but along with the Annelida. Consequently, had we been faithful to our scheme, we should have considered these peculiar beings before now; but it seemed preferable to devote a special chapter to them. The exceptional mode of life of most of them, the very complex phenomena of their development, and the unexpected light which the study of Helminthes has thrown upon some of the most obscure problems in science, amply justify the departure from the order pursued in other portions of this volume.

From our point of view, the Helminthes which lead an external and independent life, are not of any peculiar interest; the parasitic species alone merit our attention. The latter have been divided into a certain number of groups, from which we shall select the *Trematoda*, *Cestoïda*, and the *Cystic* worms.

The first are usually animals of small size, flat and

generally provided with one or more suckers, by means of which they attach themselves after the fashion of a leech. The *liver-fluke*, so common among sheep, may serve as an example of this group. The second, of which the *Tæniæ* (improperly called solitary worms) may be taken as the type, occasionally attain a length of several metres. In these worms the so-called body is composed of flattened joints, very small and slightly marked in front, but becoming gradually wider and more distinct. A rounded button-like expansion, sometimes provided with suckers, and at others with hooklets, terminates the slender extremity of this festooned ribbon. It is this expansion which is termed the head. Finally, the Cystic worms are like little vesicles, from some portions of whose surface are borne the heads of tæniæ attached to a short footstalk. The Cestoïds inhabit the digestive tube only; the Trematodes are found in almost all the viscera. The Cystic worms seem to prefer the tissues, and we find them in the midst of muscles, in the centre of the brain, &c.

All these worms are nourished, and what is more, respire, only through the intermediation of the animal which encloses them. From this fact, we can even now draw a very important conclusion, the application of which we shall find further on.

Every species of animal having its own proper form of nutriment, its special temperature and its peculiar liquids, it follows that each of them presents a series of conditions different from the others, and consequently constitutes a special world for the Helminthes. Therefore, these parasites must distribute themselves each according to its own requirements, and cannot

inhabit all forms of animals indifferently. These theoretical inductions are fully borne out by experience. Every animal supports, so to speak, its own particular Helminthes. If we were to enumerate all these parasites, we should review the entire creation, and should pry into the inmost bodily recesses of all other animals.

But whence come these strange beings, which attack the tissues and viscera in myriads, which penetrate the cavity of the skull, and even that of the eyes! Destined to lead an exceptional and, so to speak, second-hand existence, is it possible that they are produced and propagated like other animals, in fact like the very beings to which in truth they may be regarded as parasitic appendages? To reply to these questions, is to touch on another which is far more general, and which science has always handed down from age to age, to our times in which alone its solution could be attempted.

Is the creative power which has given rise to living beings extinct, or is it still exerted on this globe? In other words, is the phenomenon styled *equivocal* or *spontaneous generation* a reality?

We know the reply of the ancients. They supposed that all bodies in a state of putrefaction developed new organisms, and Aristæus' fable was only a special application of a general doctrine. These ideas universally adopted spread almost to our own days. It required the experiments and observations of Redi and Vallisnieri to convince the savans of the seventeenth and eighteenth centuries, that insect larvæ were not a product of decomposition.

From that period, more correct ideas concerning

the origin of beings began to be formed, and the advocates of spontaneous generation lost ground. They did not, however, maintain the fight, but limited the area of application of these doctrines. Now, in proportion as science progressed, this area became narrower and narrower. Then the partisans divided. Some of them, among whom we may mention Lamarck, Burdach, and Dugès, continued to regard the physical forces—light, heat, and electricity—as sufficient to organize and animate matter, so as to transform it into living beings; the others, among whom were Redi himself, Rudolphi, Morren, Oken, and Nordmann, supposed that the plastic forces in organized and living beings might suffer a sort of deviation, from which new beings, different from the first, would result. For example, according to them, portions of the vitellus of a mollusk, isolated during segmentation, would produce directly a species of infusorian; food digested under the influence of the vital force would be converted into *Tæniæ*, and certain juices destined to repair the muscular fibres would organize a series of *Cysticerci*, &c.*

* M. Pouchet and the few other naturalists who, even nowadays, constitute themselves, in *The name of progress*, defenders of these antiquated views, hold a sort of median course. M. Pouchet does not admit the spontaneous formation of an animal. He believes that the *plastic force* co-operating with the physico-chemical forces, organizes at first a *proligerous pellicle, which, in the case of spontaneous generation, exactly represents the ovary in normal generation.* It is in this pellicle and at its expense that the *spontaneous ovule* is developed.—(Hétérogénie ; ou Traité de la Génération spontanée, 1859.) This modification of the doctrine is certainly more apparent than real. The *spontaneous organization* of an *ovary*, or of an *ovule*, is in a physiological point of view a phenomenon of exactly the same order as the organization of an entire animal. The second

The first of these two views is based especially upon facts, (?) borrowed from the history of the Infusoria; the second, upon the existence of intestinal worms. On some other occasion, perhaps, we shall treat this great question of spontaneous generation in detail, and show how the experiments of Schwann and Henle demonstrated that germs * were carried into infusions, which were not protected by the improved apparatus of modern science; how Pasteur's experiments, by fully confirming those of his predecessors and revealing new truths, have overcome the final cavillings of the *Heterogenists;* and how the discovery of male and female elements in the Infusoria crowned this mass of evidence. We shall at present limit ourselves to proving, that the germs distributed through the air develop *only* the animalcules, or microscopic vegetables, that Spallanzani and so many others supposed to be produced spontaneously; that these germs have been re-collected and described by various observers; that M. Pasteur has collected and

would not seem strange to me, nor would it be more difficult for the plastic and *physico-chemical* forces than the first. M. Pouchet rejects absolutely, limits, or declares very doubtful all facts opposed to his theory. For example, he no more believes in the migrations and transformations of the intestinal worms, than he admits the accuracy of the precise and conclusive experiments of M. Pasteur. In acting thus, he is in opposition to almost all naturalists, and to all the physicians and chemists whose opinions I am conversant with.

* It is unnecessary to state that the word germ is not used in the sense employed by the partisans of evolution and the panspermists of Bonnet's school. This general expression is adopted here to designate reproductive bodies, whatever their nature, which give rise to the appearance of animals or vegetables in the liquid experimented on (spores and cellules of vegetables, ova, Infusorian cysts, desiccated animals which revive when placed in water, &c.).

sown them, as one would corn, and that half the arguments evoked in support of the doctrine of spontaneous generation are therefore annihilated.

There remain the arguments, borrowed from the history of the Helminthes, especially from the circumstance of the isolation of certain species, from the absence in them of a reproductive apparatus, and from their existence in the closed cavities and interior of the tissues. But are these arguments better based than the others? Are certain Helminthes, if not all —by an exception henceforth to be regarded as special—developed spontaneously in those localities in which the scalpel encounters them?

It is to embryogeny alone that we can look for a reply to this question, and efforts have been made for several years past to solve this latter difficulty.

Numerous and important, though isolated discoveries have been made, in France by F. Dujardin, and in Germany by Bojanus, Baër, Kölliker, Nordmann, Siebold, Wagner, and others. No intestinal worm had been observed in the early stages of its evolution. One constantly came in contact with agamic species; and it was so hard to explain their existence, that, for twenty years, even the least cautious naturalists admitted that here there must be a series of metamorphoses resembling that of insects.* Such was the state of science in 1840. We knew absolutely nothing of the embryogeny of either Cestoïd or Cystic worms.

Concerning the Trematodes, it was said that in the

* Siebold's observations on *Monostomum mutabile* were made in 1835. They prepared the way for a series of discoveries, now very considerable and constantly increasing.

viscera of fresh-water mollusks there were developed — how, it was unknown—beings called *Sporocysts*, species of living envelopes, provided with a well-marked digestive tube, but always devoid of reproductive organs. These sporocysts gave rise simultaneously to new bodies like themselves, and to germs, which became developed into *Cercariæ*, creatures in the form of tadpoles, able to inhabit water, but of quite as neuter a character as the others. These Cercariæ were the *necessary parasites* of the Sporocysts. After undergoing their development in the interior of the latter, the Cercariæ burst their walls and became encysted, somewhat like the dipterous insects we spoke of in a preceding chapter, and terminated their short lives in the prison in which they were enclosed.

We see that, according to this method of explaining observed facts, a sexless animal, of unknown origin, produces simultaneously, by gemmation, creatures like itself, and others of an entirely different character, which could never be directly produced. It would be idle to touch on the vague and evidently incomplete nature of such ideas.

Steenstrup, by his theory of alternate generation, threw a light upon these dark clouds, which seemed almost to lower in proportion as men laboured to dispel them. Supported by his own and his predecessors' researches, he boldly classed the *Distomidæ* (Helminthes of the trematode group) side by side with the Corynidæ and Medusidæ, in regard to their mode of reproduction. It was shown by the Danish savant, that the peculiar bodies then termed Sporocysts were the true *nurses* of the Trematodes, and that the

Cercariæ were the larvæ of the latter. From this period the history of the group became clearer. In 1850, Van Beneden's very important memoir appeared, in which, on the support of direct observations, he asserted that the cystic worms were nothing less than the scolices of the cestoïds.* And shortly after, this novel but important fact having been demonstrated experimentally by Küchenmeister, was published as one of the results of his first experiments. In 1853, these two writers, in competing for the Academy's prize, completed their former researches, each regarding the subject from his own stand-point, and confirming the other in many important particulars. Van Beneden, moreover, treated of the Trematodes and other groups. Since that date new facts have been announced. Gastaldi,† Filippi,‡ Siebold,§ Moulinié,|| and others, have added to our knowledge of the Distomidæ; and Lewald, Siebold, Wagener,¶ Van Beneden, Leuckart, La Vallette, and others, have repeated and extended Küchenmeister's

* "Les Vers cestoïdes ou Acotyles, considérés sous le Rapport de leur Classification, de leur Anatomie et de leur Développement."

† "Cenni sopra alcuni nouvi Elminti della Rana esculenta." 1854.

‡ "Mémoire pour servir à l'Histoire génétique des Trématodes," in the "Mémoires de l'Académie de Turin," 1854. This memoir is reproduced in the "Annales des Sciences naturelles," fourth series, vol. ii. Second memoir on the same subject, 1855; third memoir, 1857.

§ "Mémoire sur le Leucochloridium," 1854; "Mémoire sur la Réproduction des Helminthes en général," 1854, translated in the "Annales des Sciences naturelles," 1855.

|| "De la Réproduction chez les Trématodes endo-parasites," in the "Mémoires de l'Institut Génévois," 1856.

¶ "Die Entwickelung der Cestoden nach einigen Untersuchungen." 1854.

experiments; so that now, thanks to the number of their works, we can trace, if not the special history of each species, at all events, the general history of these beings, which in former days were looked on as such mysteries.

In the first place, let us treat of the Trematodes. We shall select, as an example, one of the species akin to the *Monostomum mutabile*, or the *Distomum militare*,* which have been investigated by both Siebold and Van Beneden.

The general description of trematodes already given will suffice to convey an idea of these animals. They may be described as little leeches, inhabiting the bodies of fresh-water mollusks. In the bodies of these helminthes hundreds of ova may be found, whose vitelli have already undergone their first transformations, and have become ciliated larvæ. These latter leave their envelopes, and, thus set free, make their way into the bodies of mollusks by some means or other. There they remain, and appear to undergo destruction, whilst in their places are left a number of very small ovoïd bodies, which have been developed within them.

Each of these bodies, which were regarded as *necessary parasites* by the German authors, and as *enigmatical* organs by F. Dujardin, increases in size, elongates, and acquires two lateral appendages posteriorly. This is the *sporocyst* of Baër, the "redie" of Filippi.† Judging by its movements, and its well-

* The Distomum and Monostomum are genera belonging to the Trematode *group*.

† It has been very reasonably proposed by Filippi to distinguish the transitional beings by giving them different names, according as they present a more or less complex organization, or rather

marked digestive apparatus provided with a muscular œsophagus and bifid intestine, it is impossible to deny its animality. This peculiar creature has no reproductive organ, but, to compensate for its absence, the whole internal surface of the body is endowed with the power of producing germs. The latter, buried in the general internal cavity from which they were produced, are developed sometimes into sporocysts like the first, sometimes into Cercariæ.

The Cercariæ, which for a long while were considered to be Infusoria, are like small tadpoles with an oval body, which is provided with a long tail, that serves as a swimming organ. Their organization is complex, and is in process of completion. In addition to a digestive tube, which already reminds one of that of the future Distoma, there are secretory organs, hooklets, &c., but as yet there is no trace of a reproductive organ.

When their growth is completed, the Cercariæ burst the walls of the parent sporocyst, and swim about in the water, where for a certain period they live, like infusorians. Then comes the time for their metamorphoses. They then attach themselves to some mollusk, penetrate the interior of its body, lose their tails and become encysted, almost in the same manner as the Stratiomys, of which we spoke when treating of the metamorphoses of insects. Their organism is now the seat of a process of remodelling, in every way comparable with that which we alluded to as occur-

because they are merely living saccules. For the first he proposes the term *Redies;* for the second, Sporocysts. Moulinié has adopted this distinction, showing at the same time that it is associated with different modes of formation.—"De la Réproduction des Trématodes endo-parasites." 1856.

ring among the Diptera, and the most important result of which is the appearance of a double reproductive apparatus. The Distomum gradually acquires its perfect form, and all that remains for it to do is to burst its shell, and adopt the peculiar mode of life for which it is destined.*

Here we perceive all the characters of typical geneagenesis, complicated, however, by phenomena which are related to metamorphosis properly so called.

From each ovum there is produced a ciliated larva, which gives rise by internal gemmation to a Sporocyst. The latter, by the same process, produces simultaneously new Sporocysts and Cercariæ, that is to say, *generations* which are sometimes less, sometimes more advanced in point of development. Moreover, each Cercaria passes through stages which may be compared to those which mark the evolution of an insect. It is at first free, and endowed with powers of motion like the *larva* of the Stratiomys. It becomes encysted like the latter, and by a very analogous process; and it becomes motionless, and passes, so to speak, into the chrysalis condition. Then it undergoes an organic remodelling, resembling in every respect that by which the nymph is metamorphosed into the perfect insect. Finally, in both cases the termination of these changes is marked out by the development of the apparatus which ensures reproduction by ova.

If we apply to the Trematoda the same nomenclature which we employed in the case of the other groups of which we have treated, we shall say that

* According to Steenstrup, the Cercariæ, prior to assuming their definitive features, remain encysted for nine or ten months.

the ciliated larva of the distomum is the *scolex*, and its sporocyst is the *strobila*. Each Cercaria is a *proglottis;* but in this instance the proglottis, before reaching the state of perfect distomum, undergoes a series of true metamorphoses, quite like those of insects in general, and of the Diptera especially.

These complex phenomena are further complicated by a very curious circumstance.

We met with insects living at first, when in the larval state, in water, and then in air, when the successive metamorphoses carried them to the condition of perfect insects. According to the periods of life which they have reached, these insects then inhabit different media, distinct worlds.

Now, Trematodes present a similar state of things, only in their case the media, or worlds, through which they pass in order to possess the conditions necessary to the progress of their development, are so many distinct species of animals. They must travel from one to another, and these migrations are most frequently accomplished by a process as simple as it is unexpected. The parasite is subject to the same fortune as the individual that carries it. When the latter is devoured by some other animal, the Helminth is also eaten, and travels along with the aliment, of which, indeed, it is a part. According as its new habitation is or is not suited to its requirements, it dies and is digested, or resists the solvent action of the surrounding liquids, and begins a new phase of its development.

For example, a Distomum's egg falls upon the leaf of some aquatic plant and is swallowed by a Lymnæa or Paludina; it is hatched in the interior of the mollusk,

and gives rise to a scolex (ciliated larva), which then produces its strobila (sporocyst). From the latter spring several proglottides (cercariæ), which at first swim for some time around the animal by which they have been hatched. When the period of their metamorphoses arrives, those which attach themselves to stones, leaves, and such-like, soon perish; but some of them invariably discover the larva of an insect or mollusk adapted to their wants, and pierce its integument. There they remain, till their temporary host is in his turn devoured by some frog or water-bird, and it is in the latter alone that the young Distomum completes its organization, and acquires its definitive characters.

These strange migrations, which are accomplished by a process which seems very well calculated to destroy the vitality of the Helminthes, occur also among the cestoïd and cystic worms. For there it has been proved by direct experiment; and the result of these experiments has been to show that these two groups, which hitherto had been almost universally regarded as distinct, are really but a single one. The quasi-cystic worms are only a developmental phase of the cestoïd Helminthes. The credit of having formed this conclusion, from a series of observations and perseveringly followed researches, is due to M. Van Beneden; that of having demonstrated it by precise experiments belongs to M. Küchenmeister.* Thanks to the labours of these two naturalists, and to those

* "Rapport sur le grand Prix des Sciences physiques pour 1853," by A. De Quatrefages; "Comptes Rendus de l'Académie des Sciences," 1853; and "Annales des Sciences naturelles," quatrième série, t. 1er.

of their followers, we are now in possession of a general history of the development and migrations of all these beings, which, though accepted hesitatingly at first, must be more and more regarded as truthful, in proportion as new facts are accumulated.

According to the Belgian naturalist, the Tænia's egg produces a proto-scolex, which is a little animal with an almost homogeneous body, in which it is only possible to distinguish six hooklets, or rather six very sharp spicules, arranged in three groups.* The two middle ones form a sort of lancet, and perforate the tissues placed in front of them; the two lateral pair pressing against the aperture thus formed, and working backwards, send the embryo forwards, somewhat like the manner in which a man employs his arms in hoisting himself through a trap-door. The young cestoïds are urged forwards by an instinctive impulse. Many of them perish on their journey, but some reach an organ suited to their wants, and then they are transformed into a vesicle, upon which are produced by geneagenesis the heads of the Tæniæ which are now so many *deutoscolices*.† When the animal in which these first phenomena have occurred, is devoured by some other, the vesicle disappears, the tænia-heads are isolated, and each of them develops from its posterior

* Note on the *Tænia dispar* and the mode in which the cestoïd embryos penetrate the tissues.—"Bulletin de l'Académie royale de Belgique," 1854.

† In this sketch of the development of cestoïds, which for the most part is deduced unquestionably from Van Beneden's writings, we have combined the results of his researches with those of Küchenmeister's. It was the latter who saw the vesicles which are simple at first, give rise to the tænia-heads by gemmation.

extremities a true cestoïd worm. The latter is smooth at first, but after awhile it becomes segmented, each segment being really an animal, a distinct and bisexual individual. As soon as this segment is sufficiently developed, and its reproductive apparatus is charged with fecundated ova, it is detached and expelled from the intestine, and soon dies. The thousands of eggs which it contained are swept away by the winds and mingled with the dust; thus becoming scattered in every direction. Most of them perish. A few are swallowed by some animal whose organization is adapted to their development, and each of these becomes the starting-point of a new series of transformations and migrations.

We say then, that the Tæniæ, which up to this period were regarded by most Helminthologists as simple beings, are really not only compound animals, but are true *strobilæ*, and each of their apparent joints is a *proglottis*.

These views of the Louvain *savant* have been fully borne out by experiment.

Let us select, for example, the *Cœnurus cerebralis*. This worm, which has been known for a long while, was thought to develop itself by some unknown process in the midst of the brain-substance of the sheep. It is the presence of this very unwelcome guest which produces that disease, known to cattle-dealers as *staggers*. The Cœnurus is like a semi-transparent sac filled with liquid, and sometimes as large as an egg. Numbers of heads, like those of the Tænia, are found upon its surface, and in continuity with the tissue of its envelopes. The Cœnurus is therefore a cystic worm. Like the other species of this order, it

has no trace of reproductive organ. How, then, is it reproduced?

This problem has been solved by Küchenmeister. Led by his former experiments, he fed a dog with the Cœnuri, and he soon found in its intestines the Tæniæ which till then had been regarded as peculiar to the wolf.* Next, when this worm was fully developed, he fed sheep with those segments whose eggs already exhibited embryos with six hooklets, and in a few days these sheep were attacked with

* The determination of the species thus obtained presents some difficulties, not yet quite got rid of; this fact has been dwelt on with some force by Valenciennes, and was first noticed by myself, "Comptes Rendus," 1854. But these are difficulties of detail, and do not affect the general results that I have been endeavouring to convey an idea of; the transformations and migrations of cestoïds are facts so clearly demonstrated now, that they are universally accepted. Among the works which have contributed to decide the question, I may mention the persevering researches of the two writers to whom I have already alluded, Siebold's various works, and especially two memoirs translated into French in the "Annales des Sciences naturelles," for 1851 and 1852; Wagener's important memoir, "Die Entwickelung der Cestoden," published in the "Mémoires de l'Académie de Breslau," 1854; that of Baillet, entitled "Expériences sur le *Cysticercus tenuicollis*, et sur le Ténia qui en résulte," 1861; and M. Koeberlé's work, "Des Cysticerques du Ténia chez l'Homme," 1861, &c.

It must be remembered that the experiments were not confined to the lower animals, but were made even on man himself. Leuckart experimented on his patients ("Die Blasenbandwürmer und ihre Entwickelung," 1856); Küchenmeister operated on criminals ("Gazette Hebdomadaire de Médecine et de Chirurgie," 1860). Dr. Humbert of Geneva experimented upon himself, and voluntarily produced tapeworms within himself (Bertolus, "Dissertation sur les Métamorphoses des Cestoïdes," 1856, alluded to by Koeberlé). The results of all these experiments were the same as those in the cases of the lower animals.

staggers. On killing them and opening the crania, Cœnuri in various stages of development were found in the brains. In point of fact, Küchenmeister sowed the Tæniæ in the dog by feeding him on the Cœnuri; and the Cœnuri in the sheep by feeding them on the matured segments of the Tæniæ.

The advocates of spontaneous generation ask: How, without our doctrine, do you explain the existence of so many intestinal worms, devoid of reproductive organs, and appearing in the very heart of the tissues, the muscles (*cysticercus*) and the brain (*cœnurus*)? Thanks to the writings of the distinguished naturalists whose researches we have briefly sketched, we can now reply:—These apparently agamic species are various developmental phases of truly sexual animals. In some instances, all the changes which these beings undergo, in passing from the larval to the perfect condition, have been observed, and analogy, which becomes more forcible every day, justifies us in believing that the same phenomena occur in the other species also.

This, therefore, is a result of much importance. The final argument of the supporters of spontaneous generation falls, to rise no more, and we may now, with every certainty, repeat Harvey's dictum, "Omne vivum ex ovo." Geneagenetic phenomena may mask, but they never, in the main, alter this grand law. We trust to be able to demonstrate this clearly in the later chapters of this volume.

CHAPTER XIX.

THEORY OF GENEAGENESIS.

The investigation of the attempts at a scientific explanation, which were brought about by the existence of geneagenetic phenomena, leads us to the first object of these researches,—the discovery of a common law governing the various general processes at work in the formation of animals, and the indefinite preservation of species.

Our attention has been successively drawn to these three processes—*transformation, metamorphosis,* and *geneagenesis.* With the assistance of a few examples, I have been able, without much difficulty, to mark out the application of this law in the phenomena which characterize the two first. When we came to animals in which geneagenesis presented itself, I was enabled to go more fully into details. Here I had to introduce the reader to a class of ideas little known generally; and, in order to show their peculiarities and exceptions, it was necessary to enter into a description of their variety and complication. I have now to point out the results of theory, after having spoken of those of observation; and, in order to help the reader to appreciate the different schemes of which geneagenesis is the starting-point, I must in a few words recapitulate the leading features of this phenomenon.

In animals whose development is of the geneagenetic type, the ovum, like that of animals which undergo transformations and metamorphoses, shows itself in the very outset, and gives rise to a simple being. The latter is devoid of true reproductive organs, and multiplies exclusively by fission, and by external or internal gemmæ. From these modes of reproduction, different forms of animals may result. In most instances, but by no means in all, the animal resembles neither its parents nor its offspring. After a certain number of generations the primary type is reproduced, and with it appear the sexual attributes and power of reproduction by ova. All intermediate generations developed between the extreme terms of the series are agamic, that is to say, they are devoid of true reproductive organs, and multiply by internal or external buds, and by fission, exclusively.

These are the facts: it now remains to be shown how they have been explained at different periods.

In the commencement, the only attempt made was to associate them with what was already known. Those who discovered the process of multiplication, by budding and fission in animals,—as soon as their temporary surprise had subsided,—satisfied themselves by a simple comparison with the known phenomena of the vegetable world. It was a more difficult task to reconcile the reproduction of Aphides to the generally accepted laws. Till comparatively recently, it gave rise to the most opposite explanations. Anatomy proved that hermaphroditism, although momentarily admitted by Réaumur, had really no existence here; and, in order to support the hypothesis, most naturalists limited themselves to an endeavour to prove the fact.

Of those who went still farther, the greater number, and, among others, two distinguished English entomologists, Messrs. Kirby and Spence,* asserted that a single intercommunication of the sexes was adequate to the fecundation during several generations of all the families which resulted from this union. Some, and among them Léon Dufour, the distinguished anatomist of Saint-Sever, boldly had recourse to spontaneous generation, in order to explain this remarkably exceptional fact.† Others again, as M. Morren, admitting that this opinion was not in unison with modern science, supposed that generation occurred through the *individualization of a previously organized tissue.*‡ The first of these hypotheses either explained nothing, or assumed the existence of a complete organic apparatus, which was not present. As to the theories which in a greater or lesser degree were based on the spontaneous generation doctrine, we know that at the present day they are inadmissible. Besides, all these doctrines applied to a special case, which till then had been regarded as without an analogue, and for that reason, must fall before the multiplicity and exceeding complexity of the phenomena now known.

In discovering the alternation of form and condition presented by each species of Salpa, Chamisso—and to say so is but to do him a justice that has not been

* "Introduction to Entomology."

† "Recherches sur les Hémiptères," 1853.—Annales des Sciences naturelles. Léon Dufour, who passed his life in the little town of Landes, published works on the anatomy of insects, which very soon attained great repute.

‡ "Mémoire sur l'Émigration du Puceron du Pêcher (*Aphis persicæ*) et sur les Caractères et l'Anatomie de cette Espèce," 1826. —Annales des Sciences naturelles.

sufficiently rendered—foresaw all the results of this fact considered apart, but he could go no farther. The external differences between this mode of generation and that of the Aphides were too great to admit even of a supposition of any analogy between the two phenomena.

The splendid works of Saars, Siebold, Lœwen, Dalyell, and finally of Steenstrup, by filling up the gap and forming a connecting link, alone permitted the latter to grasp relations, which till then had been imperceptible. Still, he must have had a gifted and synthetical mind to arrive at the result. Whatever may be said of the other doctrines of the Danish naturalist, this work will always be regarded as of the greatest value, and as marking an entirely new era in the history of the development of animals.

The very title of this work shows that the author considered the subject from the same point of view as Chamisso, and that he had been struck especially with the alternation of forms presented by the various generations produced in geneagenesis. This is incontestably proved by the very first passages in the book; but Steenstrup did not stop there. He pointed out clearly the physiological fact which characterizes the commencement and termination of the series of generations. This fact is, the reappearance not only of the primary form, but of all the anatomical and physiological characters also, especially of the reproduction by ova in the usual manner. This conclusion, which was at first drawn from a very small series of facts, has been confirmed by all subsequent researches. It is one of the most important truths Steenstrup has established, and one of his greatest triumphs.

In fact, from this generalization, reasonably put forward by the Danish naturalist, as the result of direct observation, two consequences follow, which are of much importance to general physiology, and which seem to have escaped those men of science who have considered this question.

Till our time, it had been usual to regard all forms of reproduction, no matter how different, as being independent of each other, and hence as possessing an equal *biological* importance. Whether it was an ovum, a bulb, or a bud, it was looked on as a primitive germ. Gemmiparous reproduction was equivalent to reproduction by ova, because in both cases the perpetuation of the species was insured.

This was clearly a deceptive view. Buds and bulbs, no matter what appearance they may assume, are only the less or more indirect products of a pre-existing ovum. The latter alone includes the essential germ, the *primary germ* of all the generations which proceed from it; consequently, buds are but *secondary germs*, and are *mediately* associated with the primary ovum. Moreover, it results from all that is at present known upon this subject, that gemmiparous reproduction does not insure the perpetuation of the species, and that after a certain period reproduction by ova becomes necessary. The latter, therefore, is the only fundamental office—it is the *function of the first order*. Reproduction by buds is merely accessory, and may hence be styled a *subordinate function*.

Further on, we shall see how much light these very simple doctrines shed on the nature of geneagenetic phenomena. We must say that Steenstrup exaggerates the truth of his view, in looking to the pheno-

menon itself for an explanation. His doctrines on this subject appear to us exceedingly hypothetical. The phases of multiplication, or rather the generations to which we have given the terms *scolex, strobila,* &c., he styles *grandnurses, nurses,* and so forth. Nor does he employ these expressions in a figurative sense, but in their special and absolute acceptations. According to him, the Medusa in its hydroid form, which produces polyps, is not a *mother* on that account; it is not a *parent* in the etymological sense of the word. It cannot be a mother, nor can it give birth to anything; and if it appears to produce buds and germs which are converted into beings like itself, it is merely because these beings have been *entrusted* to its care; that it in process of growth brings them with it. The germ pre-exists in the organs in which it is deposited, in the body in which it presents itself, and like it, proceeds from the individual primitive mother. The nurse has *no proper offspring;* her office is to *bring up an alien offspring* which she has inherited * from her own mother.

* These views are very clearly expressed in Steenstrup's fundamental work, and also in his "Objections," published in reply to Van Beneden's "Observations." They are if anything more explicit in the latter, the very words of which I have almost quoted. This circumstance, in conjunction with the passage in the opposite page, which is reproduced verbatim, will serve as a reply to the censure I received from one of the editors of the "Bibliothèque Universelle," who fancied that I was not familiar with the exact expressions of the Danish naturalist. I have not altered the text since its first appearance; I have confined myself to the removal of passages relating to some very spirited controversies which took place at the time when these articles first appeared, and which it gives me much pleasure to efface.

This is clearly the doctrine of *compound concentric germs*. In the Aphides there intervene between the two sexual generations, ten or twelve agamic ones, and, as we have also seen, an insect which is produced from a single egg gives rise to thousands of millions of individuals. Steenstrup's theory would force us to admit that the ovum contained this enormous number of germs enclosed one within the other. Such a conclusion is hardly more admissible than Bonnet's *Panspermy*.

Steenstrup endeavoured to render his views clearer by a comparison, or even by an assimilation, which, to my mind, does not appear more exact than the views themselves. He supposes that the *nurses*, or, in other words, the scolices of the Aphis, Medusa, and Salpa, represent the *neuters* in a colony of bees, wasps, or white ants, only they are placed lower in the scale of development. "A female wasp," he says, "having survived the winter, and being isolated, at first constructs a few cells, and deposits therein her eggs, from which workers exclusively are developed. As soon as these are hatched, they set themselves to work, widening the comb and increasing the number of cells. The mother now deposits a new series of ova, and from this second batch neuters are produced, and are nursed by the workers which are already there. This goes on till the workers are in sufficient numbers. Then, and then only, there spring from a few eggs, both male and female insects, and these are attended to by the neuters with the utmost care. These processes are repeated, each batch of sexual insects being preceded by one of agamic individuals destined to take charge of it, to watch the eggs, to collect the common aliment, and to feed the larvæ, &c. These neuters,

therefore, fulfil the office of nurses, and may be compared to the Medusa in the hydroid state, which carries and nourishes within itself the germ of the true Medusa. There is, however, this distinction: what the insect does voluntarily, through the operation of instinct betraying itself in acts, the Scyphistoma does through organic activity alone, and unconsciously. In both cases Nature attains the same end; viz., the completion of the final product, by the assistance, not of *intermediate generations*, but of *several broods belonging to the same generation*.

The errors of the Danish *savant's* mode of reasoning are apparent. In one instance, he asserts exactly what he wants to prove; and in another, he draws a comparison based upon results, although on his own admission the processes which produce these results are totally different.

Notwithstanding these faults, we repeat that Steenstrup's work conferred a decided benefit on science, and this service was appreciated. What seldom occurs, scientific men accepted at the very outset all the truthful views of an author, who associated together several phenomena, which till then had been regarded as isolated or anomalous: they opposed his purely theoretical views alone. Many attempts were made to re-establish them, and the controversies were occasionally of a very exciting character. We cannot enter into the details of these discussions. We shall limit ourselves to a *résumé* of the chief opinions put forward by the most competent authorities.

In the highest rank, in every respect, we must place the work of Professor Owen. This naturalist, who, from the extent of his labours, should be called

the English Cuvier, just as we might style Laplace the French Newton, published upon this subject a treatise, entitled, "On Virginal Generation.* This title is in itself the enunciation of a theory, which we regret exceedingly we cannot adopt.

In fact, the idea of virginity is inseparably associated with the possibility of the cessation of this condition. The latter supposes the existence of the apparatus which are the distinctive characters of the sexes. When these organs are absent, either from normal or accidental causes, the animal can no longer be called a virgin. This term is not applied to a eunuch, or to a deformed animal. With far greater reason it is inapplicable to a creature which has never been either male or female. Now, the results of observation and experiment go to prove that such is unquestionably the case in all the animals of which we have spoken, so long as they are in the state of scolex or strobila, so long as they multiply by buds, offshoots, or by spontaneous division. The most delicate scalpel, the most powerful microscope fails to show us, in either the Sporocyst or Scyphistoma, anything conveying an idea of sexuality.

Nevertheless, according to Professor Owen, all these beings are females. Although recognizing the difficulty found in expressing certain parental relations, he conceives that the term *mother* may be applied to them. This mode of view, adopted by the English *savant*, is based upon a very singular exception. The individuals belonging to the intermediate

* "On Parthenogenesis." 1849. In the course of this work the author proposes another term, that of *Metagenesis*, which may be translated by the words *changeable generation.*

generations of aphides possess female reproductive organs—imperfect ones, it is true, but still quite perceptible. In these organs, the essential part, the ovary, appears to be constructed upon the same plan as that of the viviparous individuals or scolices, and that of the oviparous ones, which are the true females. But in the latter we find genuine ova, with all their characteristic parts; whilst in the former we observe only small granular masses, in which we can distinguish neither a true vitellus, nor a real germinal vesicle, nor anything deserving the name of a germinal spot.*

In supposing that all animals reproduced by geneagenesis are placed under the same conditions as those which are presented by the Aphides, Professor Owen has certainly gone beyond the results of direct observation; even were it otherwise, we could not accept his theory.

In fact, Professor Owen, in explaining the phenomena, refers to the origin of the simplest organisms, and supports his views by Schwann's cell theory, a doctrine whose errors, in many particulars, we have already demonstrated. Certain beings, says the English *savant*—for example, the monads, regarded as the lowest infusoria, and the gregarinidæ, which are parasitic infusorians, living in the interior of other animals—are constituted, really, of a single cell, with its nucleus. Propagation is effected in them by division of the nucleus, which produces that of the entire animal.† Now, the ovum is formed essentially

* When on the subject of *true parthenogenesis*, we shall deal with these peculiarities.

† From the circumstances that the nature of the *nucleus* of

of a nucleated cell—the *germinal vesicle,* which encloses the *germinal spot.* The yelk, properly so called, or *vitellus,* is but an accessory mass of matter for alimentary purposes. The fundamental ovum is reproduced, just as the monad, by fission; but this phenomenon is alone determined by the intercommunication of the sexes. This act is necessary in order to infuse a certain *power,* a peculiar *prolific force** into the *germinal spot.* In consequence of this impregnation, the *germinal vesicle* disappears, the *germinal spot* becomes contracted, and the first *germinal cell* soon exhibits itself. At first, the latter divides into two, then into four, and so on, the vitellus itself undergoing, *pari passu,* the same multiplication. It is in this way that Professor Owen explains the segmentation of the yelk, and its transformation into a mass of germinal cells, invariably endowed with the prolific power which gave them birth, and which is stored up within them.

According to Professor Owen, it is invariably this mass of germinal cells which, endowed with a special force, constitutes the starting-point in the transformation of a new being. In Mammalia, all vertebrates, and in a great number of invertebrates, this

Infusoria is now known, and that this organ, which plays so important an office, is really an ovary, it is evident that many of the theories based upon Schleiden's views must be revised, and that it will be necessary to verify many of the facts which perhaps have been accepted only in so far as they were founded on those views.

* A spermatic force, a spermatic power. The arguments adduced by Dr. Carpenter and Professor Huxley in opposition to the views of their distinguished fellow-countryman, bear particularly on the supposed existence of this special force.—Medico-Chirurgical Review, 1848: "On the Agamic Reproduction and Morphology of Aphis." Transactions of the Linnæan Society, 1858.

formation is sufficient to exhaust the provision of the cells, and of the prolific force kept in reserve. In the Aphides, Medusæ, Distoma, &c., it is otherwise. A portion of the mass, composed of germinal cells, passes *unchanged* into the embryo's body, and the prolific power being still in play, the cells continue to multiply in their new abode. As soon as a sufficient quantity is formed, a new being is organized, which carries with it its own proportion of the cells and reproductive force. But, in consequence of the repetition of this process, the prolific power becomes eventually exhausted, and then only the intervention of the two sexes is necessary, in order to renew it.

All animal reproduction is the result of a single act of fecundation, brought about by the connection of the male and female, the first giving to the fundamental element, which is supplied by the second, the power of reproducing itself, during a period which varies according to the species. In reproduction by ova this force is exhausted during a single intercommunication, and must be renewed at each generation. In parthenogenesis, this force is transmitted through several generations, together with the *material elements*, proceeding from the first germinal cell. In both cases the latter is the starting-point. In it is accumulated, even at first, that prolific force which sets agoing the more or less permanent but always identical phenomena. Consequently, *parthenogenetic reproduction* differs only in point of accessory circumstances from ovarian reproduction. Fundamentally, they are one and the same phenomenon.

This is a brief sketch of Professor Owen's theory.

We may state that, in the first place, it justifies the expression *parthenogenesis*. According to this mode of view, buds, bulbs, &c., are regarded as a sort of offspring from the primitive ovum, as composed in part of the substance of this ovum, and as being at all events of the same nature. They are, so to speak, genuine ova which have been fecundated in advance. Now, the female alone produces the ova. In the main, therefore, the scolices are of this sex, and may be looked on as having some claim to virginity. Professor Owen, by reducing all modes of reproduction to a single fundamental law, simplifies all other questions, embraces and co-ordinates a great mass of scattered facts, and elucidates relations till then unperceived.

Despite all these merits, and notwithstanding the great and just authority of the author's name, Professor Owen's doctrine met with few supporters. Without alluding to what is borrowed from Schwann's cell theory, of which, in certain points, it is but a new application, we may say that this doctrine is exclusively based upon certain hypotheses which have not been borne out by facts. The disappearance of the germinal vesicle, prior to fecundation, has been demonstrated by a host of observers, not only in Mammalia, but also in Hermella and Teredo.* Now this fact is in direct opposition to Professor Owen's views; it strikes the theory at its very foundation. Moreover, since the publication of Schwann's work, many naturalists have demonstrated that the so-called segments of the yelk are by no means cells. The observations which I published at the period

* *Vide* the earlier portions of this volume.

when the doctrine of *parthenogenesis* first appeared, and which have since been confirmed, demonstrate that segmentation is a manifestation of the special vitality of the ovum, and *is not due* to the influence of the male element, which only *regulates* the process. Hence it is difficult to admit Professor Owen's special force, at least in his acceptation of it. We may add, that the accumulation of this force, its deterioration and exhaustion, are just so many hypotheses, which are doubtless exceedingly ingenious, but which are supported neither by direct observation nor by experiment.* On the contrary, the fact that among Aphides, agamic reproduction may be almost indefinitely prolonged by the employment of artificial heat, is decidedly in opposition to the English naturalist's opinions.†

* In support of his view, Professor Owen brings forward the fact that the crab's feet are not reproduced indiscriminately at all the joints, but only at those where a peculiar cellular tissue is found, which tissue he regards as a remnant of the *germinal cellular mass* still endowed with the *prolific power*. Without dwelling upon the resemblance of this explanation to that for which Bonnet was reproached, I may observe that it is deciding one question by an appeal to another, and that it is necessary, in the first instance, to prove that the character of this tissue is that which the author presumes it to be. Professor Owen asserts also that the hydra's buds are developed only at certain fixed points ; but Laurent, who devoted himself for many years to the study of this animal, proved that it has the power of budding from every portion of its body, somewhat like a plant whose adventitious buds appear in all parts of the bark, and for the same reason.

† Every doctrine put forward by so distinguished a man as Professor Owen carries with it, for that reason alone, a certain amount of influence. This is why I have reproduced in detail the statements which, on the first appearance of these essays, I thought necessary to make in opposition to his views. As I have

Leuckart, without seeking, like Owen and Steenstrup, to discover the minute nature of the phenomena, compared geneagenesis to metamorphosis.* According to his ideas, every scolex is a species of larva. The Scyphistoma is, so to speak, a medusan caterpillar. We do not think this view has any foundation, and in this we fully coincide with Steenstrup, who, beforehand, refuted most of Leuckart's arguments. "The nurse condition," said the Danish naturalist, "differs entirely from that of larva. The caterpillar is itself converted into a butterfly. The Scyphistoma never becomes an Aurelia."

The force of this reasoning is the more apparent, as we often find the two phenomena, metamorphosis and geneagenesis, in the same animal. For example, in the Medusa, after the ovum has been *transformed* into a ciliated larva, the latter is converted by *metamorphosis* into a Scyphistoma; then *geneagenesis* appears and produces the strobila, whose proglottis—which is isolated, at first, under the form of Ephyra—is afterwards metamorphosed into an Aurelia. In this case the ciliated larva is really the larva of the

already said, in these times, the expression proposed by the illustrious English zoologist would hold ground by being applied to phenomena of an entirely different order, to which the serious attention of physiologists is being drawn. The result has proved the accuracy of these preconceptions, and farther on I shall have to treat of *true parthenogenesis*, our earliest notions of which are due to Professor Owen.

* "Ueber Metamorphose ungeschlectliche Vermehrung Generationswechsel," 1851.—Zeitschrift für Wissenschaftliche Zoologie. My knowledge of this work is confined to Claparède's analysis in the "Bibliothèque universelle de Genève." But the interpreter's name guarantees the accuracy of the interpretation.

Scyphistoma, as the Ephyra is the larva of the Aurelia.

Among the Distomidæ the phenomena are still more complicated, for we find at the same time three modes of development, and three processes of metamorphosis properly so called. The ovum gives rise, *by transformation,* to a ciliated larva, which, by *geneagenesis,* produces a Sporocyst, that in its turn attains its final form by metamorphosis. The multiplication by buds, of the Sporocysts themselves, and of the Cercariæ, must be referred to *geneagenesis.* The Cercariæ are the true larvæ of the future Distomæ; and when they lose their tails and become encysted and motionless, is it not in order to pass into the *nymph* condition, after the fashion of the Stratiomys? And when, finally, they rise from this torpid state, under the form of Distomæ, is it not by a *true metamorphosis* comparable in every respect with that from which the perfect insect results?

So far from geneagenesis being a modification of metamorphosis, the facts established by the first tend rather to modify the most generally accepted ideas which have been confirmed by the second.

Assuredly, if up to the present, there is any admission to be made, it is that the offspring is the direct product of the parent; that the individuality of the germ is maintained from its birth till its death. So far as reproduction by buds has been considered as fundamental a process as reproduction by ova, these views apply equally to both. Metamorphosis does not affect them in this particular. No matter how numerous and complete the changes are which a butterfly undergoes, the animal is still one being;

the individuality is preserved. Consequently, in passing through the caterpillar and chrysalis stages, it is not the less the *direct product* of the germ contained in the ovum, nor is it the less the immediate offspring of its parents—just like the infant, which was first an embryo and then a fœtus.

But when there occurs between the two forms of reproduction such an essential relation as that the first must always constitute the starting-point of the second, this is no longer the case. The primitive germ or ovum then acquires, as we have already established, a very superior value to the secondary germs which are derived from it. The parental relations—those of father and mother to offspring—can only exist among individuals which produce such germs.

What takes place in the case of the Aurelia, for example?

From each ovum is developed a being which, at first, is single, and devoid of reproductive organs, but capable of producing spontaneously, and, as it were, from its own special substance, a great number of individuals. Each of these, in its turn, divides into a certain number of others, which acquire reproductive organs, and produce and fertilize ova. These latter are the only *true offspring* of the first parent; but they are very numerous, and all have sprung from a single ovum containing a solitary germ.

Consequently, the unity and individuality of this germ have been multiplied, that is to say, they have been divided in the process of development. The several aurelias proceeding from the single primitive ovum are only the *indirect product* of the germ enclosed

in that ovum; they are but the *mediate offspring* of their parents. This is the fundamental distinction between geneagenesis and metamorphosis.

Van Beneden's mode of view is more modest than Steenstrup's, Owen's, or Leuckart's. The Belgian naturalist has not pretended to explain the essential character of the phenomenon, but he has been especially impressed by the fact that certain species of animals are reproduced by a single process, whilst others are multiplied simultaneously by two different means. Hence he divides the animal kingdom into two classes,—*monogenetic* and *digenetic*. From this is derived the term *digenesis*, applied to the entire series of reproductive phenomena which occur without the intervention of the sexes.

To those who fully coincide with the author's views, and desire to go no farther, this term seems well conceived. It conveys a fact apart from all hypotheses; but, on the one hand, its only signification is derived from its opposition to the term *monogenesis*, which Van Beneden applies to ordinary reproduction; and, on the other, it does not seem to me to indicate sufficiently the prominent characteristics of the order of phenomena to which it refers: viz., the production of several types, and of an indefinite number of individualities, from a single primitive ovum.

This remark applies with equal intensity to the other expressions to which I have referred. It is for this reason that I propose to substitute the term *geneagenesis*, which, to my mind, is sufficiently explicit, and which only conveys a fact apart from all theoretical considerations.

Does it follow from this that all these terms should be erased from scientific terminology?—No. The words multiplication by buds, offshoots, fission, &c., and those of alternate generation, metagenesis, and digenesis, really express correct ideas and distinct facts. They will be often found useful in giving precision to language, and on that account they should be preserved. But it follows, from what has been said, that each of them must be employed to designate *one*, and one only, of the *special* forms under which geneagenesis in its most general condition may present itself.

Although very well named, this phenomenon is not explained. Moreover, we need not hope to discover the primary cause, at least not for a long while. The utmost we can do is to associate it with other facts already understood, and thus elucidate its real nature. Besides, the naturalists whose writings we have alluded to, have all striven to refer agamic generation to sexual generation, and reproduction by buds to reproduction by ova and by *fertilized ova*. This we believe to be the main cause of the difficulties they encountered.

Dr. Carpenter has taken quite another point of view.* According to this English *savant*, oviparity is an entirely different process from gemmiparity. The first requires the intercommunication of two systems of special and distinct organs; the second is simply "a multiplication of cells in the course of a continuous growth." There may be a few slight differ-

* "Medico-Chirurgical Review," 1848. I regret that I am only acquainted with this essay through Professor Owen's comments upon it in his "Parthenogenesis."

ences between Dr. Carpenter's and my own opinion as to the starting-point of the theory, and as to the mechanism by which the phenomenon is accomplished; but, with these exceptions, his general ideas agree in many particulars with my own. The following are some of the considerations which led me to this mode of view.

All forms of reproduction which we have as yet touched on, except reproduction by ova, are in reality so many processes of gemmation. This is quite evident in the Hydra, the Aurelia, and in all those animals in which the process takes place externally. Microscopic observation demonstrates that it is the same with the Biphoræ, the Helminthes, and the Aphides. But in the last-named insects, the bud, which is developed internally, is detached at a very early period, and falls into the cavity of the body, where it undergoes transformations, which bring it toward its perfect form. Here, the germ, instead of being simply a bud properly so called, is a bulb, that is to say, a deciduous bud, destined to be developed within the very animal from which it was produced.*

The very phenomenon of budding in its commencement is simply one of local growth. When a bud, whether internal, external, fixed, or deciduous, is formed at any part, it results from the accumulation, by the vital stream, of the plastic materials at one point, instead of their distribution over the entire body.

* Bulbs, properly so called, are like ordinary buds, but they become spontaneously detached from the plant which produces them, throw out roots, and give rise to a new plant, as though a seed had been sown.

Thus, all agamic reproduction is associated with *growth,* properly so called.

This conclusion, arrived at by a process of reasoning, is not unsupported by facts. When we amputate an earth-worm's head, or a lizard's tail, what first appears on the circular wound resulting from the operation? A small tubercle, an actual bud, in which we cannot at first detect either nerves, bones, muscles, or blood-vessels.* This bud increases in size, and, after a while, the various organic elements reappear; the animal reproduces the parts which had been destroyed. This is the first stage of reproduction by bulbs. The hydra, each of whose parts, when it has been divided, will reproduce a perfect animal, possesses this faculty in its highest degree. Each fragment, in modifying the accidental form resulting from the operation, has had to bud in every direction, that is to say, it has had to grow.

That is what experience teaches us. Mere ordinary observation leads us to the same result; it is even, perhaps, more demonstrative. When treating of transformation and metamorphosis properly so called, we showed how the normal growth of animals took place. We saw that this phenomenon was in some instances manifested in the *increase in volume,* and in others, in the *multiplication* of the same parts of the body; and in the latter case it frequently happens that the superadded part presents a series of organs, which almost constitute it a separate individual. For example, in

* I have made several experiments, especially upon the first of these animals, but I postpone their publication till I have completed them. I may, perhaps, bring out this work at some future period.

the Annelids, each segment throughout almost the entire body, has its own nervous centre, its own locomotive apparatus, its vascular system, digestive cavity, and reproductive organs, just like that which follows and precedes it. It would require but one step farther for each ring to carry on its own existence independently; indeed, it only wants a mouth and organs of special sense in order to do so. In *Syllis myrianis* and Naïs, the mouth and organs of sense do really present themselves, in a special segment, it is true, but one which is formed just like the others.* All the organs placed posteriorly to this abnormal head, are placed under its control. A new individuality is developed, and originates in a series of phenomena differing in no particular from those of ordinary growth, as observed throughout the whole class.

There is evidently no fundamental distinction between the phenomena just referred to, and those of gemmation in the Hydra in the Strobila, as observed by Desors, and of segmentation of the same animal, as described by Saars. The form alone of the animals, and the laws which regulate their individual growth, are quite sufficient to explain the apparent differences. Thus, the phenomenon of mammalian growth, and that of the most decided gemmation, pass, by insensible gradations, the one into the other; and all observation forces on us this one conclusion, that gemmation, and consequently agamic reproduction, are fundamentally but *processes of growth*.

* *Vide* M. Edwards' fine memoir on the embryology of the Annulosa in the "Annales des Sciences naturelles," 1845; and also my own memoir, "Sur la Génération alternante des Syllis," in the "Annales des Sciences naturelles" for 1854.

From this point of view we can at once understand how it is that agamic reproduction cannot be indefinite. Growth in every animal has its limits prearranged. If, then, gemmation be a form of growth, it, too, must have its limits; therefore it cannot suffice for the perpetuation of the species. Hence the intervention of another mode of generation, by which the continuance of the race becomes insured. As soon as the process of gemmation ceases, the ovum exhibits itself as the fundamental element; consequently, even these animals most decidedly gemmiparous and fissiparous—must, after a certain period, reproduce themselves by ova.

Once formed, the bud proceeds with its development in the same manner as any other germ, and in obedience to the same laws by which the ova of a bitch, a hen, and a teredo are converted respectively into a mammal, a bird, and a mollusk. From this, we should expect to find, in its case, all those phenomena which we treated of in our earlier chapters. Whether the bud remains fixed, as in the Hydra, till the time comes when it will have only to increase in size, or detaches itself in the condition of an almost unorganized mass, and falls into some special cavity, where it undergoes its subsequent changes, as in the Aphides, or is borne away to a distance, as in Synhydra, it nevertheless undergoes a series of *transformations* and *metamorphoses* similar to those we have described, and it is only under the influence of the *vital force* that it assumes its definitive form and proportions.

These considerations lead us to believe that the course which, in association with Dr. Carpenter, we have struck out, is really the correct one. Without

framing any new hypothesis, this mode of viewing geneagenesis agrees with all the results of direct observation and experiment; it leads from the best known and simplest facts presented by ordinary growth, to the most complex and most recently discovered phenomena of the production of generations; it explains the neutrality of all the intermediate series of the latter, accounts for multiplication by agamic individuals, and justifies the existence of cycles, which terminate in reproduction by ova; finally, it distinguishes clearly between the phenomena in question and those of metamorphoses, whilst at the same time it preserves the true relations which form a bond of union between the two classes of facts, and which cannot be denied.

It appears to me now, as it did on other occasions, that this doctrine is accurate in its entirety, as well as in its details.

CHAPTER XX.

PARTHENOGENESIS, OR VIRGINAL REPRODUCTION— FUNDAMENTAL FACTS.

We have seen that, definitively, every animal springs from an ovum, and that, mediately or immediately, it has invariably not only a *parent,* but even a true *mother.*

Is the father's existence as fully demonstrated? This is a question which the recent progress of science puts to us so forcibly, that it cannot be overlooked.*

When opposing Owen's views some six years since, I said that the expression *parthenogenesis* would cling to science, and be employed to designate a certain number of exceptional phenomena, very imperfectly known, but whose real existence seemed to me un-

* In the last century, an inspector-general of the silkworm-nurseries of Sardinia, named Constant de Castellet, having seen in the silkworm analogous processes to those we are now considering, wrote to Réaumur, asking him to examine them. Réaumur only replied, *ex nihilo nihil.* Castellet could not believe in the reality of his own observations, and therefore fancied himself deceived. We learn from this anecdote, which is borrowed from Dareste's excellent article, written three years ago, in the "Revue germanique," that Réaumur was unacquainted with Malpighi's observations, and that he acted in this instance as he had done in Peysonnel's case. Castellet was less persevering than our fellow-countryman, and thus relinquished the glory of a discovery which was only confirmed a century after his observations.

questionable, and worthy of every naturalist's attention. At this very period Siebold supported my assertions, and replied to my appeal by publishing his splendid work, which opened up an entirely new and now actively explored field of research.*

From the isolated observations on nocturnal Lepidoptera collected by Bernouilli, Tréviranus, Suckow, and Burmeister, and on the silkworm by Malpighi, Hérold, Curtis, and Filippi, it follows that certain females which have had no connection with the males can deposit eggs, which become developed, and give rise to caterpillars as active and healthy as those which spring from fecundated ova. M. Carlier, member of the Entomological Society of France, obtained as many as three original generations of *Liparis dispar*.† A belief in the virginal reproduction of *Psyche* was popular for a long while among lepidopterists, and even at the present day there are many species, the males of which are unknown. But we may associate all these phenomena with those which occur among the Aphides. Siebold being desirous of explaining the matter, studied the anatomy of the female Psyche, and unhesitatingly attributed the opinions on this question to errors in observation.‡

* "Wahre Parthenogenesis bei Schmetterlingen und Bienen." 1856. This work was analyzed fully by Young in the "Annales des Sciences naturelles," 1856; and it furnished the chief materials for Dareste's article in the "Revue germanique" for 1859. I have borrowed from it nearly all the details respecting facts which have been the start-point to all the actual researches.

† "Introduction à l'Histoire de l'Entomologie," by Th. Lacordaire. M. Carlier's last generation consisted of males alone, which, as he observes, put an end to the experiment.

‡ "Ueber die Fortpflanzungen Psyche."—Zeitschrift für wissenschaftliche Zoologie, 1849.

He had hardly made known his first opinion, when he himself observed similar phenomena to those pointed out by his predecessors, and these not only in Psyche, but in many kindred species.* At the same time he learned that the problem of ova *fertile without fertilization* had been actively discussed for four years previously by the numerous bee-culturists of Germany.

In fact, in 1845, M. Zierzon, a curate of Carlsmark, in Silesia, an unscientific man, but gifted with great powers of observation, put forward certain propositions, which caused a division between the various journals and societies then interested in the practical study of bees. Zierzon asserted that the queen-bee whilst preserving its virginity deposited ova, which, however, gave rise to males only. He supposed, with Huber, that this queen received only on one occasion the fecundating fluid to be employed during the entire period of her existence—that is to say, for several years; he added, that the queen-bee could employ this fluid as she wished, so as either to favour or prevent its contact with the ovum about to be deposited. In the first, said Zierzon, the ovum is fertilized, and produces a female; in the second, the same result follows as if the queen had remained in her virgin state, and the ovum produces only a male.†

Among the facts adduced by Zierzon and by Berlepsch, who was the first to maintain and confirm

* In *Psyche helix* and in *Solenobia lichenella* and *S. triquetrella.*

† Zierzon's researches were published in two apicultural journals for which we might now seek in vain all over Germany, but they have been carefully analyzed in Siebold's work.

the Carlsmark curate's doctrines,* are a few of a particularly interesting character, which we shall briefly allude to.

Huber's observations, and modern anatomical researches, have proved that the reproductive organs of bees are so contrived, that the union of the sexes can only occur during flight. Now, those females which, through imperfect development, or accident, or the scissors of an experimenter, have been deprived of their wings, *before union*, nevertheless deposit fertile ova, but the latter never give rise to any but male individuals.

Nay, more, if a *matron* queen be exposed to a cold temperature, capable of altering the character of the fertilizing liquid, or if through any organic lesion the communication between the pouch containing this liquid and the oviduct be cut off, she will henceforth produce males alone,† although heretofore she may have produced individuals of both sexes.

* M. Berlepsch, a skilful and well-known agriculturist, has a magnificent establishment at Seebach, which is devoted to the breeding of bees. On several occasions he has placed his apiary at the disposal of both *savants* and interested practitioners. It was with him that Siebold and Leuckart made those observations which established the unexpected phenomena of which we have been speaking. Siebold informs us, too, that Berlepsch had the honour of preserving Zierzon's views when, on account of an unsuccessful experiment, he was about to abandon them. His researches were published in the journal of apiculture entitled "Erchstädter Bienenzeitung" (Siebold).

† This was observed by M. Berlepsch. It is to this distinguished amateur also that we owe the discovery of the influence of cold; and Leuckart having made a post-mortem examination of an individual thus experimented on, found that the male element had been destroyed.

The phenomena resulting from cross-breeds support Zierzon's views still more.

In Germany, where bees are cultivated with as much care as our farmyard fowls and beasts, it was attempted to acclimatize foreign species remarkable for different qualities, and to cross-breed them with the local races, in order to improve them. One of the finest among the former is the *Ligurian bee*, which has been described by Aristotle and sung of by Virgil. Now, the hybrids resulting from its connection with the German races possessed the characters of both parents; but these traces of cross-breeding were confined to the workers and female or queen bees. The males always exhibited the parental characters in their purity. The male parent, having nothing to do with their formation, could not effect any modification of these characters.

Such are briefly the results of Zierzon's and Berlepsch's observations. Although nearly conclusive in themselves, it was necessary that they should be tested by scientific men; and to this task of confirmation Siebold and Leuckart addressed themselves. They examined dead specimens of both virgin and matron queens; they investigated the reproductive organs and the contained ova; and after a series of careful researches, they both proclaimed the truth of the facts put forward, and the accuracy of the propositions and opinions of the modest clergyman of Carlsmark.

Neither of them confined himself to mere verification. Siebold examined the silkworm from the same point of view, and re-discovered the phenomena indicated by Malpighi, Hérold, and Filippi, and then,

glancing at the invertebrata in their entirety, he showed that parthenogenesis occurred in many other groups of Insects, in Crustacea, and in Mollusks. Leuckart, on his part, investigated the virginal reproduction of worker-bees, and proved that this phenomenon, which is exceptional in our hives, occurs with the same characters, but constantly, in colonies of wasps, bumble-bees, and ants.* Then, extending his researches, he found the same phenomena, if anything, more fully characterized among the cochineal insects.† We may add that similar occurrences have since been recorded by other naturalists. For example, Messrs. Barthélemy and Millière have observed parthenogenesis in four new species of Lepidoptera,‡ and M. Hartig has discovered it in twenty-eight species of Cynips. In regard to the latter, Lubbock observes, that as yet we are only acquainted with the females, though probably parthenogenesis is much the commonest form in them.

* "Zur Kenntniss des Generationswechsels und des Parthenogenesis bei den Insecten." 1858. This work was briefly analyzed in the "Bibliothèque universelle de Genève," 1859.

† Ibid. 1861.

‡ By Millière, for two species forming a new genus akin to the Zeignes (Ann. de la Soc. Linn. de Lyon, 1857), and by M. Barthélemy in *Chelonia caja* and *Sphinx euphorbiæ* (Annales des Sciences naturelles, 1859).

CHAPTER XXI.

THEORY OF PARTHENOGENESIS.

THE phenomenon of geneagenesis, which may now be regarded as established, develops new and numerous problems for the minds of naturalists to solve. The first of these which presents itself may be thus stated. Although the reproductive bodies, which are organized without the influence of a male parent, resemble eggs, are they genuine ova?

The reply to this query has been generally in the affirmative, although we find, even in works written to justify this opinion, that the contrary is proved, at least in certain instances. Without entering into details which do not concern our present inquiries, we may consider the results arrived at by Huxley and Lubbock, two *savants* who have thrown most light upon this question.

The first, in his valuable memoir, "On the Agamic Reproduction and Morphology of Aphis,"* followed

* "Transactions of the Linnæan Society," 1858. The author has formed very different conclusions from those laid down by myself; for the tendency of his researches is to associate as much as possible the true eggs (ova) and false ones (pseudova). Among other statements, he observes, "The rudiments of the true ovum cannot be distinguished from those of the false one." The author's drawings and descriptions have convinced me that the contrary is the case. Doubtless, this difference of appreciation is due to the immense number of ova which I have had an opportunity of observing in

step by step the development of the germs in both viviparous and oviparous individuals. He thus demonstrated prominently the distinctions, as to origin, between the true and false ovum. The distinctions, in some measure involuntarily, drawn by the distinguished Professor in the "School of Mines" are very striking, especially to those who have observed the embryogeny of some of those animals which, like the Annelida and most marine Mollusca and Radiata, are best adapted to this class of investigations.

In the viviparous individuals there occur phenomena resembling those which I have met with not only in Hermella and Teredo, but in hundreds of other animals belonging to the three sub-kingdoms. In the three last chambers of the ovary of the oviparous Aphis figured by Huxley, the ovum in its embryonic state is represented by an isolated but well-marked germinal vesicle, which already exhibits its germinal spot. This vesicle increases in size as it passes through the second chamber, but it is in the third alone that it begins to be surrounded by the vitellus, whilst the germinal spot remains still clear and distinguishable.

The only difference that I can observe between the ova of these insects and those of the marine animals to which I have referred is, that we see the

my studies of marine animals. In such instances the phenomena accompanying the earlier stages of development are presented even to the uninquiring eye. The very opportunity which I have had of forming a definite conclusion since the appearance of Professor Huxley's memoir, is to my mind the most convincing proof of the value of this work. In publishing it, the author has once more shown that he deserves to be regarded as one of the most distinguished representatives of physiological zoology.

latter in all stages of development, and, in infinitely greater number, undergoing on the spot, and in the midst of the liquid of the general cavity, those changes which in the aphis take place in the various chambers.* Here, then, we find that constancy of fundamental phenomena on which I dwelt in the earlier pages of this volume. This harmony is of itself alone a proof of the accuracy of the investigations made and the structures figured by the two observers, no matter what be their method of interpreting them.

In the viviparous Aphides, Huxley describes and figures a very different series of phenomena. Here the ovarian chamber is filled with a pale homogeneous substance, which encloses a dozen cells with opaque nuclei. Portions of this material are separated from the rest by a constriction of the walls of the chamber, which becomes more and more decided. It is from it that the new being will be entirely developed. In the midst of this little mass there may indeed be seen a small transparent sphere, which sometimes presents within it a nucleus like those of the preceding cells, but of which occasionally there is no trace, and which under other circumstances is replaced by a little mass of rounded corpuscles. To experienced eyes there is nothing here to recall either the true germinal vesicle or the germinal spot, the fundamental elements of ova properly so called.

I unhesitatingly express the same opinion, in regard to the small transparent sphere, which Lubbock found

* Viewing the subject from this aspect, it is interesting to compare the figures in my memoir with fig. 2, plate 40, of Huxley's essay.

in the reproductive bodies or false ova of certain cochineal insects of the orange-tree, and to which he gave the name of germinal vesicle.* Far from being the first structure visible, it does not exhibit itself till the other parts are fully formed; the period of its appearance is irregular; and finally, to judge by the author's drawings and descriptions, instead of enclosing the true germinal spot, it always contains within it a mass of infinitely minute corpuscles. In all its features it far more closely resembles the *transparent cell* of the aphis embryo than the *germinal vesicle* of ova whose nature is established, and which should always be selected for the purpose of comparison.†

The reproductive bodies of the cochineal or kermes of the orange,‡ and those deposited by the kindred species, are all developed without any intervention on the part of the male. Nevertheless, they have been regarded as true ova, because they are covered with a shell, and are deposited like these latter. But in the manner in which they are formed, and in primitive composition, they are veritable *internal* buds, almost exactly like those of the viviparous Aphides. Is their nature altered because, from the circumstance of their being destined to be developed outside the maternal uterus, they have been provided with a more or less

* "On the Ova and Pseudova of Insects."—Philosophical Transactions, 1858.

† The reasons already given force me also to deny the term *ovum* to the reproductive bodies of Daphnia, which have been so well described in Lubbock's memoir, "An Account of the two Methods of Reproduction in Daphnia and of the Structure of the Ephippium."—Philosophical Transactions, 1857.

‡ This and a certain number of kindred species form the present genus *Lecanium* (Illiger).

solid envelope according to the accidents they are likely to incur, and which is capable of preserving them from external influences ?* Certainly not. Not more so than an ovum becomes a bud, because it never acquires a shell before it is transformed and developed within the mother's body.

But if these reproductive bodies are *buds*, and not *ova*, it then follows that development without the intervention of the male element occurs in the phenomena just considered. This is not a case of *parthenogenesis*, but one of *geneagenesis*.

This conclusion appears to me to be clearly deducible from these two series of researches, evidently carried out with extreme care, and which have been more strictly compared with each other than all the rest which have been published on this subject.† Its

* The envelopes of these pretended ova evidently vary under the conditions alluded to. They would be useless to the internal bud of the aphis, which is developed within the organs of the mother. Therefore they are not present. The internal buds of the peach-tree kermes are as well protected as the true ova, although they do not undergo their transformation till they have left the parent's body. Between these two extremes we find the internal bud of the orange-tree Kermes or *Lecanium*, which is almost entirely developed within its parent's body, and has acquired its perfect form a few hours after being deposited. Hence it is protected only by a single envelope, which Lubbock compares to the vitelline membrane ("On the Ova and Pseudova, &c."). Now that attention has been directed to this point, I am convinced that many other instances will be found which may be serially arranged in the group of phenomena referred to.

† Professor Huxley and Mr. Lubbock, between whom a friendship exists, evidently commmnicated the results of their researches to each other. It was on the invitation of the first that the interesting investigations of the second were carried out ; and in his turn, Huxley devoted his attention to the results obtained by

inevitable consequence is to throw doubt on all the hitherto implicitly accepted facts regarding virginal generation. Indeed, the revision of most of these facts appears to me to be quite necessary. Before accepting the word *parthenogenesis*, it is evidently essential to be perfectly certain that the reproductive body is an *ovum* and not a *bud*, enclosed in a more or less solid envelope. In order to do this, it is necessary to refer to the origin of the formation in question. To my mind, every reproductive body which has not the form of a germinal vesicle, with its germinal spot, belongs to the *second* category; it should possess this double and fundamental character in order to be placed in the *first* one.

To judge from what we already know, the result of this revision will be to diminish considerably the number of instances of true parthenogenesis. Will it erase them all from the book of science? I think not. In this regard I have much pleasure in coinciding with those *confrères* whose opinions I opposed in the preceding pages. Without going so far as Owen, Huxley, or Lubbock, I think that a series of intermediate stages exists between the ovum and the bud.* We have seen that such is the case with

Lubbock before they were published, in order to ascertain the accuracy of his own views.

* It is evident that, according to my view, there is quite an investigation to be made; an investigation which is essential to the progress of science. Hence it will be understood how much pleased I was to see Mr. Lubbock engaged in this labour, in the last writings of his which I have seen, and which tend to bear out some of the views which I have already put forward ("Notes on the Generative Organs and on the Formation of the Egg in the Annulosa."—Philosophical Transactions, 1861).

respect to the anatomical facts; it is the same with those of the physiological kind. It is only necessary to recall those animals which produce either males or females, according as the male parent has had any share in the process or not (bees), and especially those which deposit simultaneously ova capable of being developed, and others which perish if they have not been previously fertilized (silkworms).

There is at present nothing to warrant the supposition that in these animals the reproductive bodies have a different primitive constitution; and as some are unquestionably ova, it ought to be the same with the others.*

Notwithstanding my reservations, parthenogenesis is still to my mind a constant phenomenon. With my *confrères,* I believe that there exist true females which deposit genuine ova that are developed without any intervention on the part of the male. But I believe that this phenomenon is far less frequent than has been supposed.

Meanwhile it remains to be accounted for.

But is it possible? Is the cause of these phenomena to be found in the *fecundating action* of the older writers, in Owen's *spermatic force,* or in *hermaphroditism of the ova* as supposed by Barthélemy? These hypotheses are all gratuitous. They all lead us far from direct observation. Let us therefore leave

* To these purely theoretical reasons I may add that Leuckart's figure of the ovary of *Solenobia lichenella* seems to prove that this species, in which both he and Siebold demonstrated the existence of parthenogenesis, produces true ova, which are marked in the commencement by the presence of the germinal vesicle and spot.

them aside, and, with Huxley, frankly admit that physiology is as yet too young to solve every enigma which the Sphinx of science proposes.

But although it is wise to abstain from explanations which are evidently premature, still it is fair to make some approach to an explanation, and that is what I attempt to do.

In the earlier portions of these essays, we saw that among animals in which we have at present no reason to suppose the existence of anything like parthenogenesis, the *unfecundated ovum* demonstrates its own special vitality by a series of movements quite analogous to those which in the fecund ovum correspond to the period of formation of the new being. We have seen that in Hermella, Teredo, &c., this vitality is quickly exhausted in proportion to its exertion. Now, conceive of an ovum possessing a little more vital energy; it is evident that it will commence the process of organization. This is exactly what we find in by far the greater number of eggs of the virgin female silkworm.* Let us in imagination increase this vital power of the ovum, and we shall find it capable of forming an embryo, which is quite perceptible, but which will perish before it has been hatched.

* In the course of my investigations into the nature of the disease which committed such ravages among our silkworms, I had occasion to open several cocoons containing female insects which had never been set free; most of them had deposited eggs, yet assuredly in these instances it would be impossible to suppose the intervention of the male. In most cases the ova had changed colour, and had assumed the characteristic tints indicative of the organization of the superficial strata of their contents. In very many instances it was impossible to distinguish these ova from normal ones of the same age.

This is what Hérold saw,* and what had been also observed by Siebold. Let us suppose that—accidentally in some species, normally in others—the vital energy of the ovum is unusually intensified; then this ovum will become capable of producing by itself alone a complete animal, and we shall have parthenogenesis in all its stages, such as it is in the silkworm and the other species we have spoken of.

Seen from this point of view, parthenogenesis, it is true, is not explained, but at all events it is *associated with other phenomena*, and that alone allows us to go a step further.

Fundamentally, and from the period of the germinal vesicle condition,† the corpuscle which will eventually become the ovum is formed by the same process as that which gives rise to the bud.

Both result from the accumulation at a given point of a certain quantity of plastic material, abstracted from a pre-existing individual. Both owe their first origin to a *process of growth*.

Now, we have said already that the growth of a living being cannot be indefinite. This is why *reproduction by buds* exhausts itself or is arrested. *Reproduction by unfecundated ova* should also have a limit.

Here the great importance of the male sex makes itself apparent. But before the reader can grasp the

* "Disquisitiones de Animalium Vertebris carentium in ovo Formatione." 1838.

† In my memoirs on the embryogeny of Hermella and Teredo, I stated my reasons for believing that the germinal vesicle precedes all the other elements of the egg. I believe that in the commencement it is a homogeneous spherule devoid of an enveloping membrane.

nature of the function which I attribute to it in this series of phenomena, we must retrace our steps.

We saw that the *unfecundated ova* of Hermella and Teredo, when left to themselves, showed their special vitality by a series of movements which recalled those of the *fecundated ova;* but we also saw that these movements were soon accelerated,* became irregular, and brought about the destruction of the ova in which they presented themselves.† Now if, by artificial fecundation, we caused the male element to come in contact with these ova before the work of destruction was complete, the movements would slacken and become more regular, and a certain number of these ova, which were in process of disintegration, would give rise to as perfect larvæ as though fecundation had taken place in the commencement.‡ Here it is evident that the result of the intervention of the male would be the re-animation and regulation of the egg's vitality, which had begun to exhaust itself in a series of inordinate actions.

Hence it seems to me that the intervention of the male element, in the case of parthenogenetic phenomena, exerts a very similar influence. The repro-

* This acceleration is so well marked in Hermella's ova, that the changes of form can be almost as easily watched as those presented in the movements of an amœba.

† This destruction of the principle is certainly not due to either physical or chemical forces. Putrefaction comes on at a relatively much later period.

‡ In my memoir on the embryogeny of Hermella, I described at some length an experiment which I made on this subject, and which leaves no room for doubt.—Annales des Sciences naturelles, 1848.

duction by females only, presents several irregularities also; it tends to exhaust itself, by the very exercise of its power. The male then steps in, to restore this almost extinct property, and by the fundamental act of fecundation, establishes the necessary start-point of the production either of new individuals or of new generations.

This mode of view is, I believe, justified by all that we know at present concerning the phenomena of geneagenesis. It is evident that, in bees, the intervention of the male parent is necessary, at least once for every two generations. Judging from Carlier's experiments, there may be three generations under these conditions in *Liparis dispar*. The range is probably still more extended in *Psyche* and analogous genera.* But the intervention, at a given period, of the male, as the element requisite for the perpetuation of the species, is evidently one of the great laws of nature.

We have in some measure a material proof of this, in the external structure of the ova of the most decidedly parthenogenetic species. All of them present special apertures, intended to permit the entrance of the fecundating fluid. This is, I believe, unanimously admitted by naturalists. This existence

* I do not refer to the *Coccidæ*, as I know not how far true parthenogenesis may take place in them. Nor do I allude to the vast number of species regarded, I think, too hastily as being parthenogenetic, simply because their males are as yet unknown. For the same reason the *Lernææ* were regarded as presenting the phenomenon in question. It seems to me that naturalists who draw conclusions so rapidly, would do well to read the sage reflections which terminate Siebold's great work.

of the *micropyle* has satisfied all that it is of service sooner or later, and perhaps always.*

Definitively, the male parent is as essential as the female one to the constant duration of the species. The start-point of generations forming any series is not only *an ovum*, but *a fecundated ovum*.

Hence, all that we have said regarding buds, and of the generations proceeding from these germs, applies to multiplication by unfecundated ova, and the generations which they give rise to. They also are intermediate beings, of secondary value, interposed between the *true* parents and the *true* offspring. The circle may enlarge or alter in form, it may undergo central or circumferential changes, but it invariably becomes closed.

We have already seen that *reproduction by buds* (whether internal or external), natural and artificial *reproduction by division*, and *alternate generation* in its varied forms, are really but so many manifestations of one great phenomenon. We are led to say the same of parthenogenesis—it is only *a special form of geneagenesis*.

* Leuckart, who began by separating parthenogenesis from alternate generation, saw an essential difference between the two phenomena ; viz., that in the first, fecundation *may* occur *before every reproductive act*, but that in the second it *must* occur from time to time in *certain fixed acts of reproduction*.—Bibliothèque Universelle de Genève, 1859.

CHAPTER XXII.

GENEAGENESIS IN PLANTS—RELATION OF THE ANIMAL TO THE VEGETABLE KINGDOM.

The various facts which have been summed up in these essays lead to results of much importance to general physiology. Certainly one of the most remarkable has been the gradual establishment of a relationship between the animal and vegetable kingdoms, and the removal of some of the greatest gaps which existed, according to the ancients, between the two great divisions of living beings. This conclusion has been admitted by almost all naturalists devoted to these curious researches, from Peysonnel's time to that of Owen and Steenstrup. We ourselves have on various occasions insisted on its accuracy. In treating of Dujardin's works, we pointed out the decided resemblance which certain phenomena, observed in Medusæ, by the zoologist of Rennes, presented to those observed by Dutrochet in the Fungi.* We showed how, as regards mode of reproduction, there was an unexpected relation established between the worms of our streams and the trees of our forests, between the syllis we found at Bréhat and the date-trees cultivated by the inhabitant of the

* "Mémoires pour servir à l'Histoire anatomique et physiologique des Animaux et des Végétaux." Paris, 1837.

oases.* In proportion as researches multiplied, these relations became more numerous and general. At present we may safely assert, that wherever geneagenesis occurs, there is established between the two kingdoms, not only analogies requiring a certain mental strain for their comprehension, but an evident resemblance, and in some instances almost an identity.

It is necessary, in order to avoid being charged with exaggeration, to enter into some details, and to describe the nature of a plant or tree; but to do this, it is first necessary to know what an *individual* is, whether in the animal or vegetable kingdom.

Our ideas in this regard are sufficiently clear when we speak of a man, a pigeon, or a frog. Each of these words is associated in our minds with a certain series of parts—definite in number and relations—which collectively constitute the individual. When one of these parts is multiplied or transposed, we attribute it to an anomaly. If one of them is absent, we perceive that the individual is incomplete. This appreciation is frequently expressed by special terms, such as monstrous, blind, and maimed, which are found in almost every language.

What we have said of man, and of animals familiar to all our readers, is equally applicable to an infinite number of other species. A naturalist can say, at a first glance, whether an insect wants a leg or a wing, a Mollusk a tentacle, a Star-fish one of its rays, or a Medusa one of its filaments. He sees an incomplete individual in every *whole* which has lost one of its

* "Souvenirs d'un Naturaliste."

parts. If these same organs be more numerous than usual—albeit, their relations are but slightly changed —the naturalist will see before him so many *monstrous* individuals.

But if this same naturalist has placed before him a portion of coral, or a piece of a compound ascidian which has been slightly mutilated, he cannot now decide as he had done before, unless, indeed, the traces of its injuries indicate that some accident has befallen the object he examines. No matter how numerous the coral's branches, or the geometric figures of the ascidian may be, the most acute *savant* cannot proclaim it to be a monstrosity. From this fact alone we may conclude that neither the coral nor the ascidian plate is an individual, notwithstanding the general form which characterizes it, and which allows of its various species being distinguizhed almost at a glance.

Careful observation bears out this conclusion. In both cases we perceive a great number of beings whose aggregation constitutes an entirety. Now, each of these beings presents a series of conditions identical with those found in man himself. It is composed of parts, whose number and relations are fixed. Each of them is an animal, is a distinct individual. The polypidom and the ascidian plate are only aggregations. They are, so to speak, villages or towns, in which the polyps represent the inhabitants, and the cavities take the place of houses. Hence we can understand that both houses and inhabitants may be multiplied without altering the fundamental condition of things. Paris and Constantinople hold the same positions in the world, despite the influence of epidemics

or emigration, and although the former is as constantly enlarging its faubourgs as the latter is burning them down from time to time. It is just the same with the polypidoms and ascidian plates.

These views, though long since admitted into zoological science, were embraced at a later period by botany, although their truth is far more evident in the latter.

No matter what may be the results of vegetation, the oak and the lime are always trees; the myrtle and the rose are always shrubs. Neither the *savant* nor the ordinary observer can say that one or other of these plants is monstrous or incomplete, whether they be large or small, bushy or thickly branched, growing freely or closely clipped. The number of their parts is not determinate, therefore they are not individuals, they are only aggregations. A tree is a species of *vegetable polyp*, whose common parts are the trunk, roots, and branches.

How can we distinguish and isolate the beings which correspond to the polyps—the vegetable individuals?

Botanists are not agreed on this point. Some, who think that the leaf appears in a modified form in every organ as the fundamental element, regard it as the *vegetable individual*. Others, associating this same leaf with the condition of an organ, suppose the individuality to reside in the germ, that is to say, in the seed and bud. They consider the branch produced by either to be an individual. Many facts, and not unfrequently the same ones differently interpreted, have been brought forward in support of their views by the advocates of the two doctrines.

We are not in a position to decide between them; however, the second, which is chiefly based on embryogeny and has analogy unquestionably to support it, seems to us the more accurate of the two. Consequently *we* shall adopt it in the parallel we are about to establish between plants and animals, although Professor Owen has chosen the first. Besides, the two theories tending equally to associate the facts proved in both kingdoms, the ideas we are about to put forward will, in the main, be those already published by our illustrious *confrère;* but the form will be slightly different, and therefore we shall be led to certain considerations overlooked by our predecessors.

We have seen that the tree resembles the polypidom not only in form but in its complex nature. Neither is a simple being. The individual vegetable or animal is the fundamental element in each; both form colonies—How do these colonies increase and multiply? Here the analogies we spoke of are seen in the clearest manner. What do we first see when a new branch is about to be added to the existing ones?—A bud. What announces the appearance of a new polyp on the stalk of a *Coryne?*—A bud also.

In both cases the colony's new guest, the new individual, is but a simple accumulation of organizable matter, developed at some point in the common system, constantly receiving additions from the vital stream, and which is fashioned by the vital forces into either an animal or vegetable.

In most cases the Coryne's bud becomes an asexual polyp, provided with long tentacles, and a capacious digestive apparatus. Unfit for the purpose of repro-

duction, its office is to lie in wait for, seize and digest everything in the shape of prey which comes within reach of its arms. The nutritive juices thus prepared flow through a system of canals to the main stem of the polypidom, and then from it, to each of the individuals to which it gives attachment. The polyp to which we have alluded is, then, solely employed in nourishing the colony.

Exactly the same thing occurs in the case of the rose-tree. Most frequently the bud becomes a branch provided with leaves. The function of the latter is to abstract from the atmosphere various gaseous fluids, and especially carbonic acid; to prepare from them a liquid sap, which travels through the branches and stem to the roots; and to elaborate this compound, and convert it into a nutritive juice, which, then returning in the opposite direction, is employed in nourishing the trunk itself and all its ramifications. The leaves then are essentially the organs of absorption, exhalation, respiration, and elaboration, and the branch to which they alone are attached has only a function of nutrition to discharge.

On the rose, therefore, as on the coryne, we find certain individuals *whose sole office is that of nourishing* the colony.

At a given period the coryne gives rise to buds, which at first are like the preceding ones, but which eventually become polyps of a very different character. These new beings have neither arms nor mouth, and their digestive apparatus is quite rudimentary. To compensate for these they are provided with organs which, from the nature of their products, are judged to be sexual. If these polyps were isolated, they would

soon die from want of food; but, being nourished by their fellows, they increase and become developed, and serve to perpetuate the species. Their function is limited to this end. They are, in fact, so many *reproductive individuals*.

It is just the same with the rose. A certain number of buds, instead of being converted into branches, give rise to flowers. The leaves, having been extensively modified, and endowed with more important functions, are changed into sepals and petals, to form the perianth, and into stamens and pistils, to form the apparatus of both sexes, which here, as in many animals, are combined. The branch, thus metamorphosed, could not support itself, but is dependent for nourishment on the colony, whose propagation is ensured by it in return. It has also become a reproductive individual.

In the rose-tree, as in the Coryne, things take place in precisely the same manner.

The Coryne mother produces ova, the rose produces seeds. Here again, if we except peculiarities of form and of complication, or of specific simplicity, there is no difference between the two kingdoms. We find in both varieties of reproductive bodies, an essential part (the germ in the ovum, the embryo in the seed) which will eventually be converted into a living being. In both we observe special accessory parts, intended for the nutrition of the young animal and vegetable, and which in the ovum are styled vitellus and albumen, and in the seed perisperm and cotyledons. Both ovum and seed, too, are enclosed in more or less numerous protective envelopes, and may exist in hundreds, or be completely isolated. If, therefore, combining their general characters, we draw ideal figures of seed and

ovum, it will be found impossible to distinguish one from the other.

In the animal as in the plant, reproduction by buds takes place spontaneously, and at the immediate expense of the parent; and in both kingdoms reproduction by seed and ovum requires the intercommunication of two elements produced by special organs. Whether these organs are united in one individual, or borne by two distinct beings, the process is fundamentally the same. There is a father and a mother, a stamen and pistil; an element which fecundates, and an element which is fecundated. The ovum, when unfecundated, although almost invariably presenting its three characteristic spheres, will nevertheless possess no true germ; so likewise, the unfecundated seed will present only a rudimentary body, concealed at the base of the pistil, and devoid of an embryo.

Thus, in both plants and animals, we find agamic and sexual reproduction side by side. These two processes are placed in both kingdoms under the same conditions, and if we could enter here into technical details, we should see that they are accompanied by almost identical phenomena.

In order to observe the extent of this resemblance between the relations which unite these two modes of reproduction in plants and animals, let us do, as Professor Owen has done,—place an ovum and a seed side by side. Both have been fecundated. From the one springs a ciliated larva, from the other a primary stem, carrying two thick fleshy cotyledonary leaves, quite different from those which will succeed them. The larva becomes fixed, and is transformed into a

sort of cylindrical bud. The little stem of the rose elongates, and becomes terminated by a bud. Up to this period the polypidom, like the plant, is developed almost exclusively at the expense of the stored-up materials; by the vitellus, in the case of the ovum; by the cotyledons, in that of the seed. But from the animal bud is produced a polyp provided with tentacles for the capture of prey, and with a suitable digestive apparatus; whilst the vegetable bud becomes a stem, provided with leaves. In both kingdoms the individuals first produced have for their sole office to supply and prepare the food of the colony. Thanks to their labours, the colony is extended; new buds appear and become developed, but for a long while they give rise to *food-producing individuals* only. Evidently, the most pressing necessity is that of founding and extending the colony, and this is the only office with which the first inhabitants of these animal and vegetable cities are charged.

As soon as the special life of the polypidom and shrub is established, it becomes necessary to provide for the reproduction of these colonies. Then the *reproductive individuals* appear, male and female polyps, sometimes combined, and in the case of the plant, flowers bearing stamens or pistils, most frequently both. The first produce and fecundate ova; the second produce and fecundate seeds. All is alike in both kingdoms. The polyp, with distinct sexes, is an *animal flower;* the flower is a *sexual vegetable polyp*.

The individuals successively produced in both shrub and polypidom remain united by a common trunk; but it is very easy to understand that when a separation

takes place the relationship is fundamentally the same. Now this is precisely what occurs in certain other cases,—among the Aphides, for example; and a glance at Professor Owen's sketches will explain the matter as fully as we can in words. From the egg laid in autumn, there is developed in the following spring a neuter Aphis, which by a process of gemmation produces others like itself, this process being continued for several generations. If all these descendants of a single germ were attached to one another, we should have a regular polypidom. In being isolated at birth, their relationship is not altered. This is what Steenstrup suspected, and what Professor Owen demonstrated in a very lucid manner. The neuter Aphides correspond to the food-seeking polyps of the Coryne, and to the sterile branches of the rose-tree; the male and female Aphides represent the reproductive polyps of the polypidom, and the flowers of the rose-tree, and from our point of view may also be styled animal flowers.

Among the general facts bearing upon the class of speculations we are now engaged in, is one upon which I have often dwelt heretofore, and which I may here recall.

There is but *one* mode of sexual reproduction, whilst there are several forms of agamic generation which are found equally in the two kingdoms. In certain plants, we find, besides the true bud—the bulb—a genuine bud, like that we have referred to, but which becomes detached from the parent, and is developed by itself, as though it had been a seed. We ourselves have found this deciduous bud in Synhydra, an animal closely akin to Coryne. The lower

Algæ are propagated by spontaneous division, and the Infusoria are in no way behind them in this respect. Trembley propagated the Hydra by artificial cuttings, perhaps more extensively than any gardener ever propagated a plant by the same means. Finally, parthenogenesis shows itself in the vegetable kingdom under conditions exactly like those we met with among animals, a fact which has been dwelt on, with much reason, by both Lubbock and Dareste.

Spallanzani, whose name it is impossible to omit, when speaking of physiology, pointed out this fact as early as the last century. He found fertile seeds in the female organs of hemp, which had been carefully preserved from all external influences. But this result was too much in opposition to accepted views to be admitted then, and, on all sides, efforts were made to prove that the skilful experimenter laboured under a delusion. However, in 1820, M. H. Lecoq reproduced and extended Spallanzani's experiments, and arrived at the same conclusions.* Finally, M. Naudin, assistant naturalist in *The Museum*, investigated the matter, and his experiments, made under Decaisne's superintendence, established the fact incontrovertibly. It is now unquestionable that certain plants can produce fertile seeds, although the flower has not been submitted to the action of pollen.

Indeed, a circumstance which occurred at this very period, one may say, in all Europe, is the best proof that can be adduced of the reality of *vegetal parthenogenesis*. In 1829, Dr. Cunningham brought from

* M. Henri Lecoq, Professor in the faculty of sciences at Clermont, is now a corresponding member of the Institut.

Moreton Bay (Australia) three specimens of an unisexual euphorbium, which were placed in the Kew Botanic gardens.* These three were females. Nevertheless they produced seeds, which gave proofs of fertility. From Kew the new plant spread to the other European gardens, and, in all, produced only female forms, which invariably gave rise to fertile seeds.†

We see then that life in operating on brute matter to the production of either plants or animals, employs processes which are invariably the same; from which we are justified in concluding that in both plants and animals, agamic reproduction in all its varieties is simply a phenomenon of growth, whose result is the progressive and more or less evident individualization of a portion of the parent. This conclusion is further borne out by direct observation. It is true that the individuality of the bulb or deciduous bud detached from its parent stem, cannot be denied, but that of the fixed bud was observed at a later period; and that of any bud, whatever be its origin, can no more be recognized in a plant than in the hydra.

As in both plants and animals growth has its limits, so should agamic reproduction have its boundaries also; and here, as well as in the animal kingdom, it is impossible to propagate a species indefinitely. Conse-

* Lubbock, "Account of the two Methods of Reproduction in Daphnia."

† The *Coelebogyne ilicifolia*, which is here referred to, has been investigated by our most skilful botanists, who have with the greatest care sought in vain for a trace of male generative organs. Hence we must regard it as an example of parthenogenetic reproduction, whose cycle embraces more than thirty generations.

quently, after a longer or shorter lapse of time, reproduction by seeds becomes necessary; therefore, in plants as in animals, this alone is a function of the first class, whilst agamic reproduction is but a subordinate office. It is almost idle to comment on the harmony existing in this respect between facts and our theoretical deductions, at least in regard to plants in a state of nature.*

We see then that these *cycles of reproduction* which Steenstrup first pointed out in animals, appear in plants also. In both kingdoms these cycles commence by the development of an *ovum* or a *fertile seed*,

* The artificial propagation of vegetables by cutting, laying, and grafting, constitutes a true process of multiplication by geneagenesis. Is this process applicable indefinitely? This question which was put in the last century, has been answered in various ways. Knight went so far as to say that the life of individuals produced by different methods could not exceed in length that of the parent from which the graft, slip, bud, &c., was taken.—(Chevreul's report on Count Odart's work entitled "Ampélographie.") M. Puvis, while opposing Knight's evident exaggerations, partly embraced his opinions, and applied to animals in general, and to man himself, the views which Chevreul justly refuted. But is not the exclusive employment of these various modes of reproduction likely to result in the general deterioration or exhaustion of the individuals thus obtained? All that we have learned in these essays on geneagenesis, forces me to reply in the affirmative. Moreover I have heard that M. Cosson maintains this opinion, which he supports very ably on facts borrowed from the history of cultivated plants. It is to the abuse of the geneagenetic method of reproduction that this distinguished botanist attributes, at least in part, those general diseases which commit such havoc among our plants; it is to the same cause also that he refers the gradual disappearance of the weeping willow (*Salix Babylonica*), formerly so very common, but of which there are now in Europe only a few female individuals, which it becomes more and more difficult to reproduce by cuttings.

embrace a certain number of generations, and terminate in the re-appearance of truly sexual individuals. No matter how numerous the generations comprised by a cycle may be, all the individuals, animal or vegetable, sexual or neutral, which compose them, are still the direct or indirect product of the same ovum, or the same seed. All are therefore the mediate or immediate offspring of the male and female parents which produced and fecundated this primary germ.*

The analogies we have pointed out are maintained to the end. We know that the Hydra and Aphis which have acquired their sexual characters, perish almost immediately after having deposited their ova. The Coryne mother becomes atrophied and resorbed as soon as it has emitted its fecund germs. As soon as they have started new series of cycles and insured the perpetuation of the species, these reproductive individuals have fulfilled their mission, and therefore disappear. The life of the food-sucking individuals, on the contrary, is prolonged, for they have to support the colony and provide the materials for new buds. It is hardly necessary to remind the reader, that here also we find the analogy already observed between plants and animals. The vegetal flower, more fleeting than the animal one, fades away as soon as the seed is formed, and even before it has ripened. The floral branch, or vegetal reproductive individual, is like the hydra and the aphis mothers, and discharges its office but once in its lifetime. On the other hand, the foliaceous por-

* The words male and female parent are here employed to designate the male and female sexual apparatus, whether they are distinct, or combined in the same individual.

tions of the food-sucking individuals remain, in our evergreens, and in plants of tropical countries, just as the prey-seeking polyps of the Coryne do. And although it happens otherwise in the case of most trees in our climates, this apparent difference is explained by the circumstance that the cold of winter suspends the vital processes going on in the trunk.

Thus we perceive, that in regard to the multiplication, to the propagation of the species, the parallel between the most decided vegetables and animals subject to geneagenesis, is maintained from the period of birth to that of death.

CHAPTER XXIII.

GENERAL CONSIDERATIONS.—CONCLUSION.

We have briefly analyzed the three great phenomena presented by the animal kingdom in the development of living beings. Resuming what we have already stated in regard to each of them, we perceive that *transformation* presents itself in all, and that it alone is concerned in the development of most of the higher animals. Metamorphosis properly so called, comes next, but it is fundamentally a phenomenon of transformation which occurs beneath our eyes, instead of taking place in the depths of the organism, or when concealed by the envelopes of the ovum. Then geneagenesis presents itself; but from being essentially connected with the processes of growth and progressive individualization, it is for that reason associated with the two other phenomena.

Thus we may with certainty repeat what we asserted in the commencement of this work, that *transformation*, *metamorphosis*, and *geneagenesis*, are but three forms of one and the same phenomenon, that they bring about the same consequences, and terminate in the same result.

The conversion of a rudimentary germ into a complete individual is the final end and object of these changes of form and proportions. Hence it follows that *general metamorphosis* is essentially progressive,

and that it tends incessantly to render structures more perfect.

Doubtless, in attaining the essential, the accessory is frequently sacrificed, and the latter appears to be the case to an almost excessive degree in the recurrent development of certain animals. In these instances, too, more than in any others, the truth of the general law we have been laying down is apparent. For example, in the Lernea the entire body becomes deformed and atrophied to the advantage of a single apparatus; but the function which this apparatus has to perform is the perpetuation of the species. Hence it is the most important one, and as soon as its discharge commences, all the others are, so to speak, absorbed by it, doubtless from the circumstance that the animal is incapable of supporting all.

Apart from the apparent exceptions of the preceding instance, the character of the metamorphosis is of a most striking nature. When an animal, which undergoes simple transformations, has its development arrested at any stage, a monstrosity is produced, as the result of that circumstance alone. As to animals with geneagenesis and metamorphosis properly so called, their larvæ and scolices are always incomplete beings; they are true first sketches, which are rendered more and more perfect at each developmental phase and each new evolution, till the primitive type makes its appearance.

Metamorphosis—simple *transformation* in the more perfect animals—becomes more complex in proportion as we approach the lower divisions of the animal kingdom. *Metamorphosis properly so called* is quite exceptional among the vertebrates. It is only

general among the members of the other sub-kingdom, and in these it is more complete the lower we go. There is an immense difference between the caterpillar (the butterfly's larva) and the little ciliated creature which is the larva of the Hermella. The former is a very complex animal, which performs important functions; the latter is, so to speak, only a vitellus, enclosed in its blastoderm, and clothed with cilia. It is because the caterpillar belongs to a superior, and the ciliated larva to an inferior member of the same sub-kingdom.

Geneagenesis is controlled by the same law. Its phases become more numerous and better defined, in proportion as we descend in the scale of beings. It is the exception among Articulata, but becomes the rule among radiate animals.

Proportionally as metamorphosis becomes complex, it renders the naturalist's description of any species less simple.

Among animals which undergo *transformation* this description is simple enough. The important modifications take place out of sight, and we have only to sum up the features resulting from changes of the external characters of the young beings, and the distinctions which exist between the male and female. In animals with *metamorphoses properly so called*, the difficulty is increased. In insects, one must be acquainted with the larva, nymph and perfect animal, of the latter of which there are always male and female. In the Teredo one must be familiar with a series of forms, which are quite as well marked, but far more variable. Finally, in animals with *geneagenesis*, we must embrace the characters of four or five

beings whose forms and modes of life are quite dissimilar, if we desire to know the species. Had not experience informed us, who could have suspected the existence of the Distoma under its forms of ciliated larva, Sporocyst, and of free and encysted Cercariæ?

Metamorphosis, under the form of *geneagenesis*, not only complicates the idea which the mind conceives of any particular species, but it even extensively modifies our general and abstract notions of species. Up to this, we have understood by this word a succession of beings proceeding one from the other, and whose individuality is maintained despite a number of minor less apparent changes. At present, we must add to this, that, in certain cases, the species is composed of perfectly distinct beings, which proceed one from another by a process of multiplication. To the idea of *continuity of individuals*, which forms the basis of all existing definitions, we must connect that of *succession of cycles*. This is what was first understood by Chamisso, and was fully demonstrated by Steenstrup.

The general phenomenon which we are now considering seemed for a long while, under its forms of *true metamorphosis* and *geneagenesis*, to supply an argument to the advocates of spontaneous generation. Until the time of Rédi and Vallisnieri, insect larvæ were thought to be formed by the action of the physico-chemical forces on decomposing organic matter. Even in a few modern works it is asserted that the intestinal worms are the immediate products of the animal in which they are found. We have seen that the best-ascertained facts lead to a diametrically opposite conclusion. For a long period it has

been known that the caterpillar proceeds from two pre-existing butterflies; and we mentioned how recent investigations demonstrated the origin of the Cercariæ, Cysticerci, &c. We are now aware that all those neuter individuals which reproduce without the intervention of sexes, and whose multiplication was so long a mystery, are the equivalents of simple buds. We have shown that the bud and *unfecundated* ovum can only produce individuals, or at the utmost a few generations; and, finally, we have proved that to the *fecundated* ovum alone belongs the task of perpetuating the species.

Now, in order to carry out this general law, it is necessary that there be a female to secrete the ovum, and a male to fecundate it. Hence every animal proceeds, mediately or immediately, from a father and mother;* and what we here assert of animals applies, as we have seen, with equal force to vegetables. Consequently the discoveries, relative to geneagenesis, strike at the very lowest foundations of the *spontaneous generation* doctrine.

Every living being originates in a father and mother, that is to say, in a male and female. The existence of sexes, of which there is not a trace in the inorganic world, is the distinctive character of organized nature, is, in fact, one of those primordial laws instituted in the beginning of all things, and which we must lay aside, at least for the moment, in order to discover the reason of it. With a few exceptions, which doubtless are more apparent than real, we may

* As we stated before, the terms father and mother apply respectively to the individual generative apparatus when the two are united in the same being.

say that the organic world has had a sort of double creation; that there are two worlds—male and female. Very close relations of co-existence may be found between the two; but they may invariably be distinguished, and it is truly remarkable, that their separation is an indication of high organization. These two worlds appear indistinguishable only among the very lowest members of both kingdoms. Hermaphrodites are only found in the inferior groups of the four sub-kingdoms. This character is not presented by any of the leading classes of these great divisions; and with the exception of certain fishes, not a single vertebrate is hermaphroditic.* Thus the union of the two sexes in one individual, so far from being a sign of superiority, is one of true degradation, and indicates in some measure a monstrosity.

Metamorphosis attains its greatest manifestation in *geneagenesis*. The latter, which originates in a simple process of growth, evidently commences by transformation; but among the Medusæ and intestinal worms it is still further complicated by *metamorphosis proper*, and thus comprises the general phenomenon in all its phases.

From that circumstance alone we may conclude that it is accomplished by the processes we have already described. The proofs of this conclusion are neither difficult of production nor will it take us

* M. Dufossé, a physician of Marseilles, called attention to facts which had been well nigh forgotten, and demonstrated that in the various species of the genus *Serranus*, a very well-marked hermaphroditism is found. This is at present the only exception to the rule amongst vertebrate animals.

very long to enunciate them. Is not the first formation of the bud essentially a process of *epigenesis*, its growth one of *simple evolution*, and are not its modifications so many phenomena of *complex evolution*? Is not the imperfect condition of the organs of reproduction of the neuter Aphis, the result of an actual *arrest of development*? Do not the histories of the Medusæ, Distomæ, and Tæniæ supply us with a thousand examples of the *production, destruction*, and *appropriation of organs*? Can we in this more than in any other instance understand these results, without admitting the existence of the *vital vortex*? Certainly not. The latter reappears with the character of the general process pointed out in the earlier pages of this volume.

We have then, as it were, returned to our starting-point. Let us for a moment dwell upon this fact, and deduce certain conclusions from it.

We saw that the *vital vortex* presided over transformation. It alone enabled us to comprehend metamorphosis; it alone explained the far more complex phenomena of geneagenesis. It is impossible to avoid seeing a fundamental law, and in some measure also an immediate cause of the development and completion of living beings, in the exercise of this twofold movement of arrival and departure. Notwithstanding the assertions of some naturalists, who desire to arrest their inquiries at this stage, it is necessary to refer this fact to some higher cause; for matter, which is of itself inert, can only be set in operation by the impulse of some force or agent. Every material operation is at first an *effect* before, in its turn, it becomes a *cause*. What, then, is the agent which is

here at work in matter? Shall we, like some physiologists, invoke the six or eight forces admitted by chemists and natural philosophers, in explanation of the phenomena occurring in inorganic matter?* Long ago we gave the following reply to this question:†—Yes; in organized beings we find the phenomena of heat, light, and electricity; chemical affinity and capillary attraction are momentarily manifested, and possibly we may also find in them processes analogous to those of catalysis and epipolism. But these phenomena are accomplished, and these processes carried on, under the influence of a far higher power, whose existence it is in truth impossible to deny. Electricity, heat, and chemical affinity operate in living beings, and are certainly engaged in the production of the *vital vortex*. Nevertheless, they labour only under the control and regulation of a superior force—life, which modifies all brute forces, and causes them to produce muscle and blood instead of ammoniacal salts;

* Chemists and natural philosophers accuse naturalists of endeavouring to cloak ignorance with a word, in supposing the existence of a special force in order to account for the series of phenomena characteristic of living beings. It is true that astronomers explain the motion of the heavenly bodies by the hypothesis of gravity alone; but in explaining the action of their instruments, or the products of their laboratories, both chemists and physicists invoke in their turn, light, gravity, heat, electricity, and magnetism; others add, affinity, capillarity, endosmosis, catalysis, epipolism, &c.; all these for mere inorganic matter! After showing that they themselves are so little exacting, it is indeed dealing generously with naturalists, to deny them the right of supposing one solitary force more, to preside over such characteristic, varied, and complex phenomena as those of living beings!

† In my "Souvenirs d'un Naturaliste," and in many articles in the "Revue des deux Mondes."

bones instead of phosphate of lime; and plants and animals, instead of mere inorganic lifeless masses.

All force is blind, and must necessarily be directed. In order to produce a certain determinate species and not a kindred one, in order to avoid being lost amid the various paths of metamorphosis and geneagenesis, it is requisite that even life itself should be placed beneath the control of something still superior.

This something is the specific nature of each being, that which each plant and animal has received from its ancestors, through the intermediation of the seed or ovum from which it was produced, and which it will transmit to its descendants by the intermediation of the germs which it gives rise to in its turn. If we could go back for generations and ages, we should still find the same questions presenting themselves, and invariably similar facts would give rise to like replies. In order to explain organic nature, it would be necessary to refer to the very origin of all things.

But here, observation and experiment, those two guides which human science ought never to lose sight of, are absolutely unavailing. The true philosopher feels compelled to pause, lest he should set his foot in a land of hypotheses and conceptions, where it is so easy to wander from the proper path, and where truth itself —supposing it to be attainable—cannot be distinguished by any certain test.

THE END.

COX AND WYMAN, PRINTERS, GREAT QUEEN STREET, LINCOLN'S INN FIELDS.

USEFUL WORKS.

Peter Schlemihl.

From the German of ADELBERT VON CHAMISSO. Translated by Sir JOHN BOWRING, LL.D., &c. Crown 8vo., cloth, with Illustrations by George Cruikshank, price 2s. 6d.; the Illustrations on India paper, price 5s.

Whist.

The Laws and Practice of Whist, as played at the London Clubs. By CŒLEBS. With coloured Frontispiece. 16mo., cloth, gilt edges, price 2s. 6d.

Horse Warranty:

A Plain and Comprehensive Guide to the Various Points to be noted, showing which are Essential and which are Unimportant. With Forms of Warranty. By PETER HOWDEN, V.S. Fcap. 8vo., cloth, price 3s. 6d.

Graceful Riding:

A Pocket Manual for Equestrians. By S. C. WAITE. With Illustrations. Fcap. 8vo., cloth, price 2s. 6d.

"In the school, on the road, on the course, or across country, this little book will be invaluable; and we heartily recommend it."—*Morning Post.*

The Plagues of our Domestic Animals, and their Prevention.

Being Lectures delivered by Professor GAMGEE at the Royal Agricultural College, Cirencester. To which is added the Report of the Congress of Veterinary Surgeons held at Hamburg in 1863.

The Science and Practice of Farm Cultivation.

By Professor BUCKMAN, F.L.S., F.G.S. Fully Illustrated, price 7s. 6d., bound in cloth; each part separately, price 1s.

1. How to Grow Good Roots.
2. How to Grow Good Grasses.
3. How to Grow Good Clover.
4. How to Grow Good Corn.
5. How to Grow Good Hedges.
6. How to Grow Good Timber.
7. How to Grow Good Orchards.

Hardwicke's Shilling Handy-Book of London.

An Easy and Comprehensive Guide to Everything worth Seeing and Hearing. Royal 32mo., cloth, price 1s.

CONTENTS.

Bazaars.
Ball-rooms.
Cathedrals.
Dining-rooms.
Exhibitions.
Mansions of Nobility.
Markets.
Money-order Offices.
Omnibuses.
Palaces.
Parks.
Passport Offices.
Picture Galleries.
Popular Entertainments.
Police-courts.
Prisons.

Shilling Guide to London Charities.

Showing, in Alphabetical Order, the Name, Date of Foundation, Address, Object, Annual Income, Number of People benefited, Mode of Application to and Chief Officers of every Institution in London. By HERBERT FRY. Published Annually.

A Manual of Geography:

Being a Description of the Natural Features, Climate, and Productions of the various regions of the Earth. By FRANCIS MORTON, C.E. Limp cloth, 1s.; Bound in Leather, with coloured Maps, 1s. 6d.; in paper, without Maps, 6d.

On Obscure Diseases of the Brain and Disorders of the Mind.

By Dr. FORBES WINSLOW, D.C.L. Oxon, &c. Third and cheap Edition, price 10s. 6d.

"The unanimous voice of home and foreign commentators has reiterated approval of this standard work. It is the text-book of English medical psychology, and such it must continue as long as accurate description of vital phenomena is prized by the physician. The volume is a vast clinique, faithfully and graphically portraying the author's practical observations."—*Lancet.*

A Popular Manual of Physiology:

Being an Attempt to Explain the Science of Life in Untechnical Language. By HENRY LAWSON, M.D., Professor of Physiology in Queen's College, Birmingham; and one of the Lecturers on Natural Science, under the Science and Art Department of the Committee of Council on Education. Fcap. 8vo., with Ninety Illustrations, price 2s. 6d.

The Influence of Railway Travelling on Public Health.

From the *Lancet*. Fcap. 8vo., cloth, price 1s.

Country Cottages.

A Series of Designs for an Improved Class of Dwellings for Agricultural Labourers. By JOHN VINCENT, Architect. With numerous Plans, Elevations, &c. New Edition, Folio, fully Illustrated, price 12s.

Method for Teaching Plain Needlework in Schools.

By a LADY.

It is a constant source of complaint that servants know not how to work well at their needle, and those who visit their poorer neighbours lament the total ignorance in this respect; many cannot cut out or make even so simple an article as a child's pincloth.

This useful method is based on *steps* which are *gradual, well-defined*, and clear to the *perception*. It is calculated to insure the improvement of each individual child, and, while it offers the necessary instruction to the less talented pupil, it enables the more clever one to attain the highest degree of perfection. Price 2s. 6d. Illustrated by Diagrams and Samplars.

USEFUL WORKS—*continued.*

The County Families;

or, ROYAL MANUAL of the TITLED and UNTITLED ARISTOCRACY of the Three Kingdoms, is now ready in one splendid volume. It contains a complete Peerage, Baronetage, Knightage, and Dictionary of the Landed Commoners of England, Scotland, Wales, and Ireland, and gives a brief notice of the descent, birth, marriage, education, and appointments of each person, his heir apparent or presumptive, a record of the offices which he has held, together with his town address and country residences. By EDWARD WALFORD, M.A., late Scholar of Balliol College, Oxford. Price £1. 16s. 1,200 Pages; 11,000 Families.

By the same Author,

The Shilling Peerage.

The Shilling Baronetage.

The Shilling Knightage.

The Shilling House of Commons.

A Corner of Kent:

Some Account of the Parish of Ash next Sandwich; its Historical Sites and existing Antiquities. By J. R. PLANCHÉ, Rouge Croix Pursuivant. Demy 8vo. fully illustrated.

MR. PLANCHÉ'S WORK ON HERALDRY.

Heraldry founded on Facts;

or, THE PURSUIVANT OF ARMS. By J. R. PLANCHÉ, Rouge Croix. Second Edition, with additional Notes and more than 200 Illustrations from the most authentic sources. Demy 8vo. cloth, with Illuminated Frontispiece, price 6s.

An Essay on Heraldry.

By JACOB FREDERICK Y. MOGG, Member of the British Archæological Association. Second Edition, Demy 8vo., price 2s.

How to Address Titled People.

Companion to the Writing-Desk; or, How to Address, Begin, and End Letters to Titled and Official Personages, together with Tables of Precedence, copious list of Abbreviations, Rules for Punctuation, and other useful information. Royal 32mo., price 1s.

A Hand Catalogue of Postage Stamps for Collectors.

By Dr. JOHN EDWARD GRAY, F.R.S., F.L.S., &c., of the British Museum. Price 1s.; Interleaved as Album, 2s. 6d., gilt edges.

LONDON: ROBERT HARDWICKE, 192, PICCADILLY.